IEEE

EDUCON MADRID 2010

E D U C O N

IEEE EDUCON 2010 Conference

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

Proyecto TIN2009-07577-E

eMadrid

ANECA AGENCIA NACIONAL DE EVALUACIÓN DE LA CALIDAD Y ACREDITACIÓN

2010

POLITÉCNICA

FACHHOCHSCHULE KÄRNTEN

IEEE Education Society

IEEE EDUCON 2010
IEEE Engineering Education 2010
The Future of Global Learning in Engineering Education

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April 14th - 16th, 2010, Madrid Spain

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EDUCON 2010 – Annual Global Engineering Education Conference
The Future of Global Learning in Engineering Education.

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WELCOME FROM IEEE EDUCON 2010 CHAIRS

It is well documented that our modern society is characterized by rapid developing and ever-changing political, social, economical, technological and environmental situations. Consequently, our society of the 21st century makes great demands on its members in virtually every aspect of their lives. Members of the society must now keep pace with these mutable situations, adapt their skills and expertise with agility, collaborate, and compete to provide value to society. Technology subjects and the engineering domain are, in particular, affected by this situation.

As a result of this, educational approaches have changed over the last century from remedial repetitive learning to today's learning, which focuses on acquiring an understanding of how to become more independent in the learning process. Learning is no longer concentrated mainly in the first stages of human life through formal education and specific training in business, but it becomes a day-by-day routine over a human's life cycle. This situation requires new forms and channels in the learning process. Additionally, modern learning approaches must account for social and cultural aspects as well as the individual's profile including task and role-based aspects, interests, knowledge state, short-term learning objectives and long-term career goals. Thus processing and acquiring knowledge is a key to a modern learning pedagogy, but also content creation, collaboration and community-based practice for knowledge and skills development are important success factors.

IEEE Education Society partnership with the IEEE Region 8, is beginning a new global engineering education conference, IEEE EDUCON, held each year in selected cities throughout Europe, the Middle East, and Africa. The conference provides an interdisciplinary forum for academic, government and industrial collaboration on teaching methods, practical experiences and research toward improving the future of global engineering education. The IEEE EDUCON conference will attract participants from all over the world and will provide an interdisciplinary forum for academic, research and industrial collaboration on teaching methods, practical experiences and research towards the future of global Engineering Education.

The conference will cover papers in the categories of: research, development, evaluation and best practices that deal with learning Engineering Education in academic, organizational, and life-long learning settings including, but not limited to the following areas and their associated topics:

- Area 1: Infrastructure and Technologies for Engineering Education
- Area 2: Innovative Materials, Teaching and Learning Experiences in Engineering Education
- Area 3: Knowledge and Competencies in Engineering
- Area 4: Educational Methods and Learning Mechanisms in Engineering Education
- Area 5: Attracting, Engaging and Retaining Human Talent to Engineering

Manuel Castro (Spanish University for Distance Education, Spain), Edmundo Tovar (Technical University of Madrid, Spain) and Michael E. Auer (Carinthia Tech Institute Villach, Austria)
EDUCON 2010 Conference Chairs

IEEE EDUCON 2010 CONFERENCE PROGRAM

Wednesday, April 14th, 2010 – Madrid
CONFERENCE VENUE: UNED. Faculty of Humanities and Faculty of Sciences
Location: Campus "Senda del Rey", close to "Puente de los Franceses"

9:00 - 9:30 - EDUCON 2010 Opening Ceremony

9:30 – 10:30 - Keynote Speaker Session – Susan Lord - IEEE Education Society: Global Leader in Engineering Education

11:00 - 12:00 - Session: 01A Area 4: Learning Models - Competency and Teaching methodologies

Session: 01B Area 3: Specific Engineering Disciplines - Researches

Session: 01C Area 1: Collaborative and Social Technologies - Social Computing

Session: 01D Area 1: Computer and Web based Software - Web based services

Session: 01E Area 1: Computer Supported Collaborative Learning - For use in projects

Session: 01F Area 1: Intelligent Learning Systems

Session: 01G Area 3: First Year Courses and Programs

12:15 - 13:15 - Session: 02A Area 3: Skills Development: Technical Writing, Presentation, Teamwork

Session: 02B Area 3: Knowledge and Competencies Management - Competencies

Session: 02C Area 2: Innovative Engineering Courses and Labs - Laboratories

Session: 02D Area 2: Laboratory Experiences: on-site and remote environments - Remote Labs

Session: 02E Area 5: Lifelong Learning and Nontraditional Students - Theories and Courses

Session: 02F Area 4: Pedagogies

Session: 02G Area 1: Learning Objects reusability and digital repositories

14:30 - 15:30 - Session: 03A Area 2: Innovative Competitions and Laboratories - Detectors and robotics

Session: 03B Area 2: E-Assessment

Session: 03C Area 4: Rethinking Pedagogy in Engineering Education Multidisciplinary issues

Session: 03D Area 1: Computer and Web based Software – Physics Applications

Session: 03E Area 1: Wireless, Mobile and Ubiquitous Technologies for Learning

Session: 03F Area 1: Open Source, Open Standards, and Federated Systems

Session: 03G Area 3: New Frameworks for Engineering Education

15:45 - 16:45 - Session: 04A Area 4: Learning Models - Learning tools

Session: 04B Area 4: Active Learning - Project based learning

Session: 04C Area 2: Virtual Worlds for Academic, Organizational, LifeLong Learning and training - Virtual environs

Session: 04D Area 4: e-Assessment and new Assessment Theories and Methodologies - Methods

Session: 04E Area 1: Computer Supported Collaborative Learning - Proposals and Methodologies

Session: 04F Area 3: Degree Programs and Curricula

Session: 04G Area 5: Gender Issues in Engineering Education

17:00 - 18:30 - Session: 05A Area 1: Learning Systems Platforms and Architectures - Platforms and Learning Tools

Session: 05B Area 3: General Issues in Engineering Education - Improving students performance

Session: 05C Area 2: Innovative Engineering Courses and Labs - Courses

Session: 05D Area 1: Computer and Web based Software - Programming

Session: 05E Universia Special Session: International Engineering Cooperation

Session: 05F LiLa Special Session: Library of Labs - LILA Project

Session: 05G e-Madrid Special Session- eMadrid: Research and Development of e-Learning Technologies in the Madrid Region

Thursday, April 15th, 2010 – Avila
CONFERENCE VENUE: Avila's Conference Center (Centro de Congresos y Exposiciones Lienzo Norte de Ávila)
Location: Avenida de Madrid, 102 - 05001 Ávila

9:30 - 10:30 - Session: 06A Area 1: Uses of Technology in the Classroom – Engineering Applications

Session: 06B Area 3: Specific Engineer ing Disciplines - Prac tical pro jects in Engineering

Session: 06C Area 1: Collaborative and Social Technologies Experiences

Session: 06D ICOPER Special Sessi on: Assessing Assessm ent For mats - ICOPER Network

11:00 - 12:00 - Session: 07A Area 2: Inn ovative Competition s and Labora tories - Dig ital, Communication and analytic issues

Session: 07B Area 3: Knowledge and Competencies Management - Knowledge

Session: 07C Area 4: Rethinking Pedagogy in Engineering Education - Project based learning and research

Session: 07D Area 2: Laboratory Experiences: on-site and remote environments - On-line Labs

Session: 07E Area 5: Attracting and Retaining practices in Enginee ring Education

12:15 - 13:15 - Session: 08A Area 1: Learning Systems Platforms and Architectures – Virtual and Remote Labs

Session: 08B Area 4: Active Learning - Methodologies and analytic studies

Session: 08C Area 2: Design Experiences - Subject methodologies in design

Session: 08D Area 3: General Issues in Engineering Education – Innovative Experiences

13:45 - 14:30 - Keynote Speaker Session – Patricia Manson - Learning in the 21st century: Technology-Enhaced Learning and European research

14:30 - 14:45 - EDUCON Awards Ceremony

IEEE EDUCON 2010 Meritorious Service Award - Dr. Russel Meier

IEEE Education Society Chapter Achievement Award 2009 - Portugal Chapter - Jose Salvado, Jose Carlos Metrolho, Co-Chairs

Friday, April 16th, 2010 – Madrid
CONFERENCE VENUE: UPM. School of Forestry Engineering and UPM's Central Headquarters
Location: Campus of "Ciudad Universitaria"

9:30 - 10:30 - Session: 09A Area 1: Uses of Technology in the Classroom - Learning Experiences

Session: 09B Area 4: Active Learning - Collaborative learning

Session: 09C Area 1: Collaborative and Social Technologies - Collaborative and projects works

Session: 09D Area 4: e-Assessm ent and new Assessm ent Theories and Methodologies - Theories

Session: 09E OCW-Universia Special Session : OCW and Open Educational Resources

Session: 09F VISIR Special Session: W orkshop on VISIR electrical and electronic remote lab: Principles and educational view

11:00 - 12:00 - Session: 10A Area 1: Adaptive and Personalized Technology-Enhanced Learning

Session: 10B Area 3: S pecific En gineering Disciplines - Proffesional Developments

Session: 10C Area 2: Virtual W orlds for Academ ic, Organizational, L ifelong Learning and training - Virtual media and tools

Session: 10D Telefónica Special Session: T elefonica University Chairs Network

Session: 10E Area 5: Lifelong Learning and Nontraditional Students - Practical experiences

Session: 10F VISIR Special Session: Practical Workshop on VISIR electric and electronic remote labs

12:15 - 13:15 - Session: 11A Area 4: Learning Models - Methods

Session: 11B Area 3: General Issues in Engin eering Education - Theories and studies about learning layouts

Session: 11C Area 2: Design Experiences - Tools and procedures

Session: 11D Area 1: Computer and Web Software - Security and Data Bases

Session: 11E ANECA S pecial Session: New Directions in Engineering Accreditation, Quality and Course Design

Session: 11F Area 2: Laboratory Experiences: on-site and remote environments - Didactics for experimentation

13:15 – 13:45 - Keynote Speaker Session – Javier Uceda - Innovation in Engineering Education

14:30 – 15:00 - Educon Closing Ceremony and Awards

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Location

Wednesday 14, Madrid
CONFERENCE VENUE: UNED. Faculty of Humanities and Faculty of Sciences
Location: Campus "Senda del Rey", close to "Puente de los Franceses"

Thursday 15, Ávila
CONFERENCE VENUE: Avila's Conference Center (Centro de Congresos y Exposiciones Lienzo Norte de Ávila)
Location: Avenida de Madrid, 102 - 05001 Ávila

Friday 16, Madrid
CONFERENCE VENUE: UPM. School of Forestry Engineering and UPM's Central Headquarters
Location: Campus of "Ciudad Universitaria"

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IEEE EDUCON 2010 Areas and Topics

Areas

- **Area 1:** Infrastructure and Technologies for Engineering Education
- **Area 2:** Innovative Materials, Teaching and Learning Experiences in Engineering Education
- **Area 3:** Knowledge and Competencies in Engineering
- **Area 4:** Educational Methods and Learning Mechanism s in Engineering Education
- **Area 5:** Attracting, Engaging and Retaining Human Talent to Engineering

Area 1: Infrastructure and Technologies for Engineering Education

- Learning Systems Platforms and Architectures
- Adaptive and Personalized Technology-Enhanced Learning
- Intelligent Learning Systems
- Computer Supported Collaborative Learning
- Open Source, Open Standards, and Federated Systems
- Standardization, Reusability and Interoperability Issues
- Learning Objects reusability and digital repositories
- Experiences in OpenCourseWare Engineering Education
- Computer and Web based Software
- Uses of Technology in the Classroom
- Semantic Web and Ontologies for Learning Systems
- Web 2.0 and Social Computing for Learning and Knowledge Sharing
- Data Mining and Web Mining in Education
- Collaborative and Social Technologies
- Synchronous and Asynchronous Technologies
- Wireless, Mobile and Ubiquitous Technologies for Learning
- Ambient Intelligence and Smart Environments for Learning
- Standardization, Reusability and Interoperability Issues

Area 2: Innovative Materials, Teaching and Learning Experiences in Engineering Education

- Laboratory Experiences: on-site and remote environments
- Undergraduate Research Experiences
- Design Experiences
- Innovative Engineering Courses and Labs
- Digital Game and Intelligent Toy Enhanced Learning
- Affective and Pervasive Computing for Learning
- Human-Centered Web Science and its Applications to Technology-enhanced Learning
- E-Assessment
- Virtual Worlds for Academic, Organizational, Life-long Learning and training
- Innovative Competitions and Laboratories

Area 3: Knowledge and Competencies in Engineering

- Knowledge and Competencies Management
- Accreditation Issues
- Assessment and Feedback
- Degree Programs and Curricula
- First Year Courses and Programs
- General Issues in Engineering Education
- Specific Engineering Disciplines
- Faculty Development
- Globalization: Preparing Faculty and Students
- Graduate Curricula and Programs
- New Frameworks for Engineering Education
- Skills Development: Technical Writing, Presentation, Teamwork

Area 4: Educational Methods and Learning Mechanisms in Engineering Education

- Rethinking Pedagogy in Engineering Education
- e-Assessment and new Assessment Theories and Methodologies
- Active Learning
- Learning Models
- Pedagogies

Area 5: Attracting, Engaging and Retaining Human Talent to Engineering

- Lifelong Learning and Nontraditional Students
- E-learning in the Workplace
- K-12 Initiatives and Partnerships
- Study Abroad Programs
- Attracting and Retaining practices in Engineering Education
- Technology Enhanced Learning for students with special needs
- Accessibility in On-Line and Technology Enhanced Learning
- Gender Issues in Engineering Education
- Cultural Issues in Engineering Education
- Attracting Women to the Engineering Profession

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Martin Ebner,	Graz University of Technology, Austria
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EDUCON CONFERENCES AND THE FUTURE

The Engineering Education Conference (EDUCON) will provide an interdisciplinary forum for academic, research and industrial collaboration on teaching methods, practical experiences and research towards the future of global Engineering Education attracting 200+ participants from all over the world. Participants will include university presidents, college deans, department chairpersons, faculty in engineering and engineering technology, and industry leaders from throughout the IEEE Region 8 (Europe, Middle East and Africa) and the world.

IEEE EDUCON conferences are organiced from the IEEE Education Society in collaboration with academic and professional entities of IEEE Region 8 (Europe, Middle East and Africa). For this reason the conference is expected to yearly move around IEEE Region 8 (2010 in Europe, 2011 in Middle East and 2012 in Africa, beginning again in 2013 in Europe).

IEEE EDUCON 2011

Amman, Jordan
IEEE EDUCON 2011 will be organized by Princess Sumaya University of Technology.
Chairs: Abdullah Y. Al-Zoubi, Michael Auer and Edmundo Tovar

IEEE EDUCON 2012

Africa

TOPICS AND SESSION CODES IN EDUCON 2010

The papers presented in EDUCON 2010 Conferen ce, have been organized in the following development areas and topics, mainly based in technical and educational resources. Every session has been addressed by a wide knowledge and extense experience chair.

Session	Topic and Area
01A	Area 4: Learning Models - Competency and Teaching methodologies
01B	Area 3: Specific Engineering Disciplines - Researches
01C	Area 1: Collaborative and Social Technologies - Social Computing
01D	Area 1: Computer and Web based Software - Web based services
01E	Area 1: Computer Supported Collaborative Learning - For use in projects
01F	Area 1: Intelligent Learning Systems
01G	Area 3: First Year Courses and Programs
02A	Area 3: Skills Development: Technical Writing, Presentation, Teamwork
02B	Area 3: Knowledge and Competencies Management - Competencies
02C	Area 2: Innovative Engineering Courses and Labs - Laboratories
02D	Area 2: Laboratory Experiences: on-site and remote environments - Remote Labs
02E	Area 5: Lifelong Learning and Nontraditional Students - Theories and Courses
02F	Area 4: Pedagogies
02G	Area 1: Learning Objects reusability and digital repositories
03A	Area 2: Innovative Competitions and Laboratories - Detectors and robotics
03B	Area 2: E-Assessment
03C	Area 4: Rethinking Pedagogy in Engineering Education - Multidisciplinary issues
03D	Area 1: Computer and Web based Software - Physics Applications
03E	Area 1: Wireless, Mobile and Ubiquitous Technologies for Learning
03F	Area 1: Open Source, Open Standards, and Federated Systems
03G	Area 3: New Frameworks for Engineering Education
04A	Area 4: Learning Models - Learning tools
04B	Area 4: Active Learning - Project based learning

Session	Topic and Area
04C	Area 2: Virtual Worlds for Academic, Organizational, Life-long Learning and training - Virtual Environs
04D	Area 4: e-Assessment and new Assessment Theories and Methodologies - Methods
04E	Area 1: Computer Supported Collaborative Learning - Proposals and Methodologies
04F	Area 3: Degree Programs and Curricula
04G	Area 5: Gender Issues in Engineering Education
05A	Area 1: Learning Systems Platforms and Architectures - Platforms and Learning Tools
05B	Area 3: General Issues in Engineering Education - Improving students performance
05C	Area 2: Innovative Engineering Courses and Labs - Courses
05D	Area 1: Computer and Web based Software - Programming
05E	Universia Special Session: International Engineering Cooperation
05F	LiLa Special Session: Library of Labs - LILA Project
05G	e-Madrid Special Session- eMadrid: Research and Development of e-Learning Technologies in the Madrid Region
06A	Area 1: Uses of Technology in the Classroom - Engineering Applications
06B	Area 3: Specific Engineering Disciplines - Practical projects in Engineering
06C	Area 1: Collaborative and Social Technologies - Experiences
06D	ICOPER Special Session: Assessing Assessment Formats - ICOPER Network
07A	Area 2: Innovative Competitions and Laboratories - Digital, Communication and analytic issues
07B	Area 3: Knowledge and Competencies Management - Knowledge
07C	Area 4: Rethinking Pedagogy in Engineering Education - Project based learning and research
07D	Area 2: Laboratory Experiences: on-site and remote environments - On-line Labs
07E	Area 5: Attracting and Retaining practices in Engineering Education
08A	Area 1: Learning Systems Platforms and Architectures - Virtual and Remote Labs
08B	Area 4: Active Learning - Methodologies and analytic studies

Session	Topic and Area
08C	Area 2: Design Experiences - Subject methodologies in design
08D	Area 3: General Issues in Engineering Education - Innovative Experiences
09A	Area 1: Uses of Technology in the Classroom - Learning Experiences
09B	Area 4: Active Learning - Collaborative learning
09C	Area 1: Collaborative and Social Technologies - Collaborative and projects works
09D	Area 4: e-Assessment and new Assessment Theories and Methodologies - Theories
09E	OCW-Universia Special Session: OCW and Open Educational Resources
09F	VISIR Special Session: Workshop on VISIR electrical and electronic remote lab: Principles and educational view
10A	Area 1: Adaptive and Personalized Technology-Enhanced Learning
10B	Area 3: Specific Engineering Disciplines - Proffesional Developments
10C	Area 2: Virtual Worlds for Academic, Organizational, Life-long Learning and training - Virtual media and tools
10D	Telefónica Special Session: Telefonica University Chairs Network
10E	Area 5: Lifelong Learning and Nontraditional Students - Practical experiences
10F	VISIR Special Session : VISIR Special Session: Practical Workshop on VISIR electric and electronic remote labs
11A	Area 4: Learning Models - Methods
11B	Area 3: General Issues in Engineering Education - Theories and studies about learning layouts
11C	Area 2: Design Experiences - Tools and procedures
11D	Area 1: Computer and Web based Software - Security and Data Bases
11E	ANECA Special Session: New Directions in Engineering Accreditation, Quality and Course Design
11F	Area 2: Laboratory Experiences: on-site and remote environments - Didactics for experimentation

KEYNOTES SPEAKERS

Susan M. Lord – Professor and Coordinator of Electrical Engineering, University of San Diego, San Diego, CA, U.S.A. President of the IEEE Education Society

Susan M. Lord received a B. S. with distinction in Electrical Engineering and Materials Science and Engineering from Cornell University and the M.S. and Ph.D. in Electrical Engineering from Stanford University. Author of over seventy publications, her teaching and research interests include electronics, optoelectronic materials and devices, service-learning, feminist pedagogy, lifelong learning, and engineering student persistence. From 1993-1997, Dr. Lord taught at Bucknell University. She is currently Professor and Coordinator of Electrical Engineering at University of San Diego (USD). Her research has been supported by several National Science Foundation (NSF) grants from various programs including a CAREER grant, instrumentation and laboratory improvement (ILI) grants, scholarships for STEM (SSTEM), gender in science and engineering (GSE), and innovations in Engineering Education. She is the Guest Co-Editor of a special issue of the International Journal of Engineering Education on Applications of Engineering Education Research. Dr. Lord has worked at SPAWAR Systems Center, NASA Goddard Space Flight Center, AT&T, and General Motors. She is a member of the IEEE, ASEE, SWE, and Tau Beta Pi. She has served on the national administrative boards of the IEEE Education Society (EdSoc) and the ASEE Education and Research Methods (ERM) Division. Dr. Lord served as the General Co-Chair of the 2006 Frontiers in Education (FIE) Conference and has served on the FIE Steering Committee since 2006. Dr. Lord served as Vice President of EdSoc for 2007-2008 and President for 2009-2010.

IEEE Education Society: Global Leader in Engineering Education

The IEEE Education Society (EdSoc) is pleased to be a sponsor of EDUCON and technical co-sponsor of TAEE. EdSoc leaders view this conference as vital for carrying out the mission of our society and believe that EDUCON will be at the forefront of global Engineering Education in the future. In this talk, I will describe some of the history of the Education Society, its recent strategic planning process, and its hopes for the future. What is the Education Society? In April 2009, EdSoc leaders developed new vision and mission statements to introduce EdSoc to the world. The vision of EdSoc is “The IEEE Education Society strives to be the global leader in Engineering Education”. The mission is “The IEEE Education Society is an international organization that promotes, advances, and disseminates state-of-the-art scientific information and resources related to the Society’s field of interest and provides professional development opportunities for academic and industry professionals”. Currently, EdSoc has about 3000 members globally including 30% from IEEE’s Region 8 (Europe, the Middle East, and Africa) and 10% from Region 9 (Central and South America). Strengths of the Education Society include being globally engaged, recognized, and sought after to collaborate in educational innovation, generating quality publications and conferences, and dedicated leadership.

Patricia Manson – Head of Unit, Cultural Heritage and Technology Enhanced Learning in the Directorate General Information Society and Media of the European Commission.

Patricia Manson has worked at the European Commission since the early 90s on ICT applications areas in the Community's research programmes and for the past 4 years has been involved in defining the research agenda and subsequent workprogramme for technology enhanced learning research and for its implementation through the funded projects. Prior to joining the Commission she worked in the UK on a research-funded post providing technology and market watch, as well as information and advisory services to the cultural heritage community on the adoption of ICTs.

Learning in the 21st Century: Technology-Enhanced Learning and European Research

The presentation will explore the challenges facing learning in the 21st century and describe the role of European research in technology enhanced learning in this changing context. Experience has revealed the importance of giving equal weight to the technologies, to the learning and to the improvements in learning and this balance is at the core of technology-enhanced learning.

Javier Uceda – Professor of the Automatic Control, Electronic and Computer Engineering Department at Technical University of Madrid. Rector of Technical University of Madrid

Javier Uceda received the M.Sc. and Ph.D. degrees from the Universidad Politécnica de Madrid (UPM), Madrid, Spain, both in electrical engineering. Since 1986, he has been a Professor of electronics with UPM. He has published several books and more than two hundred and fifty papers in international journals and conferences and he holds several national and international patents. He has been a member of the Editorial Board of the European Power Electronics and Drives Journal. His research activity has been developed in the fields of Power Electronic and Digital Electronic Systems where he has participated in numerous national and international research projects. His main contributions are in the field of switched-mode power supplies and dc/dc power converters for telecom and aerospace applications. In the year 2000 he was appointed Vice-Rector for Research and Institutional Relations of the Technical University of Madrid, a post which he occupied until his election as Rector of the same University in March, 2004

Dr. Uceda is currently Fellow of the IEEE and a Senior AdCom member of the IEEE Industrial Electronics Society. He is a member of the Editorial Board of the European Power Electronics and Drives Journal and belongs to the Executive Council of the European Power Electronics and Drives Association where he is Vice-President. He has been Associated Editor of IEEE Transactions on Industrial Electronics. He was the Technical Program Committee Chairman of the IEEE Power Electronics Specialists Conference in 1992 and the General Chairman of the European Conference on Power Electronics and Applications in 1995. Prof. Uceda is also member of the Scientific Advisory Board of the Center for Power Electronics Systems (CPES), sponsored by the National Science Foundation in USA. Has received several individual and collective awards among which stands out the IEEE Third Millennium Medal.

Innovation in Engineering Education

Engineering is changing as a consequence of scientific and technological evolution and society needs and demands. Engineers need to understand the structure and behaviour of matter from nanoscale to extremely complex systems. Convergence of scientific and technological disciplines requires also an interdisciplinary approach in education. In this presentation some of the challenges and possible orientations in Engineering Education will be discussed.

IEEE EDUCON 2010 AWARDS

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Best Paper Awards are appointed in the following categories:

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CONTRIBUTIONS TO IEEE EDUCON 2010

EDUCON 2010 Conference, has been structured in 57 normal sessions, 9 special sessions and a non tradicional paper session.

Session 01A Area 4: Learning Models - Competency and Teaching

Competency-Based Pedagogical Wrapping
Atif, Yacine
UAE University (United Arab Emirates)

Consequences of the Declining Interest in Engineering Studies in Europe
Maillet, Katherine; Porta, Marcela
Telecom & Management Sud-Paris (France)

Adjunt Enterprise Professors in the European Higher Education Area
Aguiar, Javier M.; Baladrón, Carlos; Carro, Belén; Sánchez, Antonio
Telefónica I+D (Spain); University of Valladolid (Spain)

Competence certification as a driver for professional development: A IT-related exploratory case-study
Coelho, Joao Vasco
ISCTE (Portugal)

Competency-Based Pedagogical Wrapping

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Abstract—**In this paper, we propose a novel learning-framework that is context dependent. We adopt a broad definition of learning context, encompassing learning domains and learner competencies. Context-based learning requires dealing with three major research thrusts: pedagogical categorization, learner modeling, and context matching techniques. The system architecture relies on a context matching engine and a set of pedagogical learning patterns to re-purpose learning objects according to contextual situations. A prototype is implemented on top of a common learning service registry, which supplies learning schema that map a given learning context and a learner profile, as well as instances of instructional learning services.**

Keywords-pedagogy; learning personalization; learning design; semantic Web; Web services; design patterns.

I. Introduction

Significant progress in reusability of learning resources have been made [1, 8, 4, 6, 2]. Learning however, is not just about contents but also about the process through which content is repurposed into personalized learning patterns [9, 5, 3], which map instructional contents into experiential learning activities. Yet, this external pedagogical know-how is not conveyed in a reusable manner to field experts and learning interface designers. Process-oriented learning (instead of content-based approaches) is facilitated in this paper through adaptive learning patterns.

Figure 1 shows a taxonomy of learning specification models, where learning operations are highlighted. At design-time, content is provisioned and related patterns are advocated. Learning patterns are encapsulated into learning schema to reflect a subject-related learning prescription. A learning schema models possible evolutions of learning styles and constraints throughout an instruction process. The annotation of learning resources to standard packages, such as IEEE LOM (Learning Object Metadata which specification is available at *http://ltsc.ieee.org*) and the publication of related active services used to retrieve those packages are performed in the implementation-time phase of learning specification. Finally, run-time specifications address interfacing issues to accommodate accessibility requirements, and provide means for context-acquisition to trigger further dynamic pattern reconfiguration.

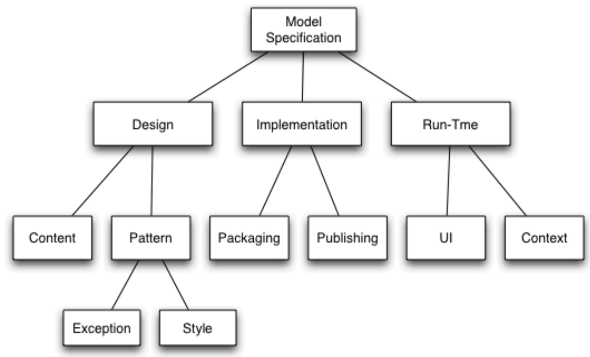


Figure 1. Learning Taxonomy

This paper proposes an approach to learning design which integrates learning patterns as standard learning services with tuning configuration parameters based on learner profiling criteria through standard LIP (Learner Information Package) specification. A learning process schema is introduced as a learning modeling capability to map contextual-dimensions via predefined pattern templates. The remaining sections of this paper are as follows: first, we provide some background and related work, which are relevant to the presented work in this paper.

In the remaining sections we first provide some background and state the problem addressed in this paper. Then we specify in Section 3 learning patterns as reusable educationalist-devised pedagofical templates, followed in Section 4 by learning designs to model learning patterns. We conduct an system prototype implementation in Section 5 as a proof of concept, and conclude the paper with a summary of results and suggested future directions.

II. Background and Problem Statement

Learning production is delivered in a standard layered-model shown in Figure 2. Typically, at the base level of the learning model is the domain model, which is an ontological structure to reason about the domain itself. It conceptualizes domain-related knowledge and defines semantic relationships, independently from pedagogical concerns. The subsequent layer of the learning model routes pedagogical goals and constraints via logical rules to operate over the domain model base layer. Goals refer to the sought-after competency levels, whereas learning-institutions, pedagogical requirements or personal learning-contexts may impose constraints.

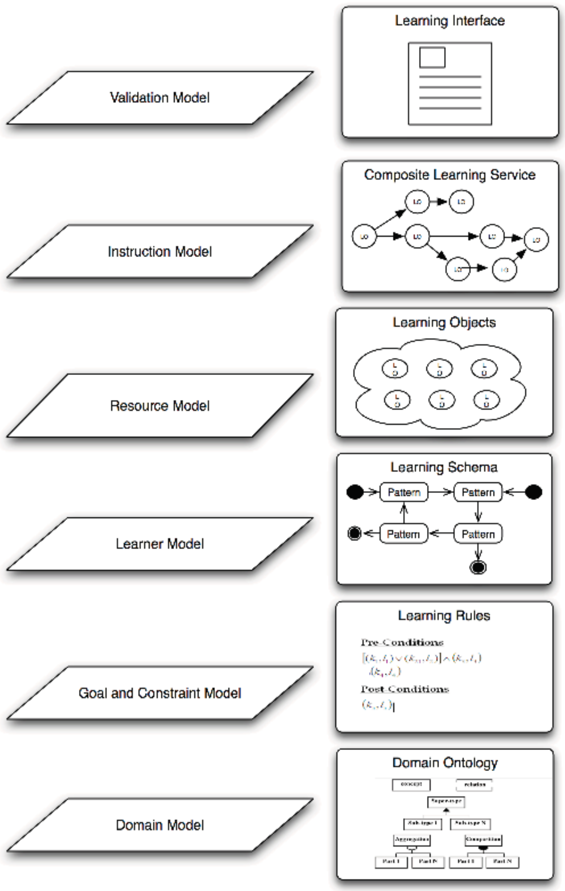


Figure 2. Learning Model

The third layer represents the learner model, which accumulates knowledge about learner profiles based on which, domain content can be wrapped into reconfigurable learning patterns. Pattern-specific learning tasks are prescribed at run-time to adapt to pedagogical recommendations and goals specification, based on pre-conditional rules consideration and post-conditional competency assessment. The learning resource layer shown in Figure 2 consists of learning services which access distributed repositories of Learning Objects or LOs. Learning services, implemented as standard Web services, subsume learning contents into standard packages defined by IEEE LOM specification. The course model choreographs a scenario of learning services as directed by a schema of learning patterns defined in this paper, through a service composition process.

The separation of functionalists into modular production units calls also for a separation of learning-provisioning roles, giving an opportunity to contribute at different levels of learning design. Learning content is tuned at each level to fit variety of profiles. Domain expert for example, may configure content to fit varying degrees of background. Pedagogues may instead mold learning content into activity patterns to adapt to a wider range of learning style. Instructional designers may package learning patterns into standard units and publish related services for learning distribution. Another possibility is for an HCI designer to advocate a presentation facade that is adjusted to specific learning services or customized to specific learning profiles.

Trends in providing personalized learning can be achieved by developing an open composition scheme of versatile learning-services provision within a multilevel enterprise integration framework such as the one shown in Figure 3. There is a lack of approaches today that enable open, enterprise-wide integration of learning, which empowers passive learning-structures such as LO to display a polymorphic behavior to fit learning patterns. In the learning architecture shown in Figure 3, lower layer modules are passive data structures that encompass raw learning-data at the bottom level, as well as structured learning resources and knowledge to package and reason about learning domain, at the upper level.

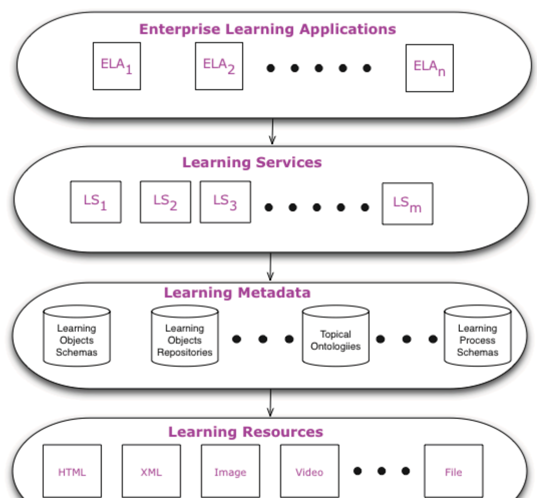


Figure 3. Enterprise Learning Architecture

III. LEARNING PATTERNS

As highlighted earlier, authors from different expertise horizons, like Content Experts, Instructional Designers, Pedagogues, etc, statically design instructional instances in each dimension of learning processes. In doing so, they retrieve an exiting instance of a given learning dimension and enumerate all possible instances across another dimension that fall onto their domain expertise. For example. A "Computer Science" pedagogue may consider an "Operating System" learning content and develop related activity patterns such as experiential learning cases through laboratories, pointers to discussion forums on the subject, problem-based practice lessons, etc. This authoring process may require an exhaustive enumeration of possible learning patterns, to match a wider range of typical learning profiles.

A. Learner Profile

Working out a learner's profile through some stereotypes can happen using the standard IMS Learner Information Package (LIP). This would permit to identify appropriate capability-enabled learning services. LIP is a specification of standard means for recording information about learners. It is designed to access information about learners, as well as their progress records. In doing so, LIP facilitates the transfer of learner-related information across different learning services or applications. As shown in Table 1, IMS LIP specification is structured in eleven groupings aimed at personalizing learning experiences in a general form. These groupings include Identification, Goal, QCL (Qualifications, Certifications or Licenses), Accessibility, Activity, Competency, Interest, Affiliation, Security Key, and Relationship.

TABLE I. LEARNER INFORMATION PACKAGE SPECIFICATION

Category	Explanation Explanation	Tag
Identification	Key bibliographic and demographic data about learner	<identification>
Goal	Career and other objectives and aspirations of an individual learner	<goal>
Qualifications	Qualifications, certifications and licenses granted by recognized authorities	<qcl>
Activity	Any learning-related activity in any state of completion	<activity>
Transcript	Summary of academic achievements	<transcript>
Interest	Hobbies and other recreational activities of a learner	<interest>
Competency	Skills, knowledge and abilities of a learner	<competency>
Affiliation	Learner's membership in different professional organizations	<affiliation>
Accessibility	Learning preferences as well as language capabilities, disabilities and eligibilities	<accessibility>
Security Key	Set of passwords and security codes assigned to a learner	<securitykey>
Relationship	Relationship between core data structures	<relationship>

Our approach exploits the inter-relationships between LIP elements to define learning patterns for an individual learner, within cognitive preferences, acquired competencies and expected learning goals, as shown in Figure 4. Competencies could be communicated in a suitable format to match learning patterns.

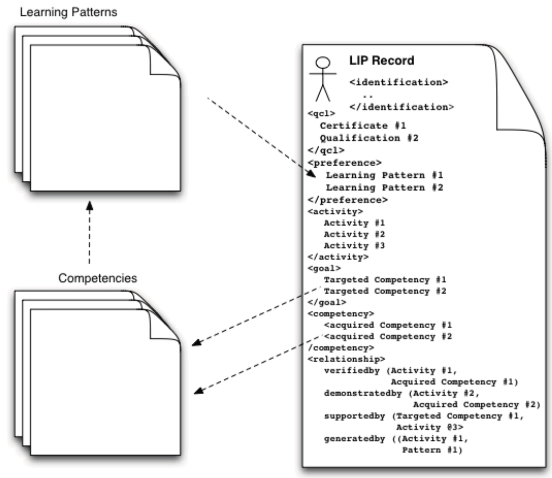


Figure 4. Learning Pattern

B. Learning Styles

Just as some people are left-handed, we learn better following different styles. A renowned educationalist David A. Kolb, has made an inventory of possible Learning Styles [7]. These learning modes are deemed to be responsive to contextual demands. According to Kolb, learners perceive and process information in a continuum from a concrete experience to testing implications as follows:

- Concrete Experience (CE): being involved in a new experience (feeling)
- Reflective Observations (RO): watching others or developing observations (seeing)
- Abstract Conceptualization (AC): creating theories to explain observations (thinking)
- Active Experimentation (AE): using theories to solve problems and make decisions (doing)

Depending upon the situation or the environment, learners may enter the above learning modes at any point. Below are some brief illustrative examples in applying Kolb's styles within different domain contexts:

- Abstract conceptualization - Listening to explanations and theoretical presentations.
- Concrete experience - Going step-by-step through an equation.
- Active experimentation — Practice on solving problems.
- Reflective observation - Recording thoughts about algebraic equations in a learning log.

Kolb's model offers both a way to understand individual learning styles, which he named the "Learning Styles Inventory" (LSI) [7], and also an explanation of a cycle of "experiential learning" that applies to all learners. Hence, our motivation to consider Kolb's model for defining learning patterns that can suit a variety of learning profiles. Kolb developed four learning styles: Diverger, Assimilator, Converger, and Accommodator. Learners generally prefer some of the four styles above the others or may move between styles in different learning domain contexts to reinforce retention. Kolb thought of these learning styles as a continuum that one moves through over time and hence, these are the main styles that instructors need to be aware of when creating instructional materials, particularly domain pedagogues. This instruction development approach results in four types of learning patterns:

1) Accommodators Pattern - (Concrete experience/Active experimenter pattern)

Learners who are exposed to this pattern are motivated by the question, "What would happen if I do this or that?" They look for significance in the learning experience and consider what they can do to move to the next stage. They like also to accumulate previous case scenarios elaborated by other learners. Example of instruction methods to create learning instances of Accommodators pattern include:

- Provide opportunities for independent discovery.
- Develop an active learning environment.
- Anticipate questions, such as "What if?" and "Why not?

2) Assimilators Pattern - (Abstract conceptualization/Reflective observer pattern)

Learners are eager to answer questions like, "What is there to know precisely?" They like accurate, organized delivery of information. They tend to pull a number of different observations and thoughts into an integrated whole. They also prefer to reason inductively and create models and theories before moving to design projects and conduct experiments. Instructional methods that suit Assimilators include:

- Lecture method (or video/audio presentation)—followed by a demonstration.
- Lab exploration, following a prepared tutorial for which answers should be provided.
- Independent study works and analytical exercises.

3) Convergers - (Abstract conceptualization/Active experimenter pattern)

For this type of learners, relevancy or the "how" of a situation are dominant learning-behaviors. Application and usefulness of information is increased by understanding detailed information about the system's operation. They tend to emphasize the practical application of ideas and solving problems. They like decision-making, processes and problem solving as well as practicability side of concepts. Finally, they prefer technical problems to interpersonal issues. Typical instruction methods that suit convergers include:

- Interactive instruction (i.e. not passive).
- Computer-assisted instruction.
- Exploring problem sets or workbooks.

4) Divergers - (Reflective observer/Concrete Experience pattern)

These learners are motivated to discover causality relevancy or "why" of a situation. They like to reason from concrete, specific information and to explore the information presented to them in a detailed, systematic and reasoned manner. They emphasize innovative and imaginative approaches in doing things. They view concrete situations from many perspectives and adapts by observation rather than by action. They like cooperative groups and brainstorming activities. Instructional methods that suit divergers include:

- Lecture focusing on specifics such as the strengths, weaknesses and uses.
- Hands-on examples. – Interaction sources with the instructor.
- Ready reference guides and organized summaries.

A learning profile may include several learning patterns. Content providers and pedagogues should use the above guide to develop learning packages. Each learning schema has one or more learning pattern. And each learning pattern belongs to exactly one learning schema. The line ended with a filled diamond between a learning schema and a learning pattern, denotes this composition relationship. This means, that a learning schema may encompass one or more learning patterns.

IV. Learning Design

We define a learning schema to encapsulate diverse learning pattern specifications, which are instantiated based on contextual information. Learning pattern models are behavioral approaches to learning. Learning schema is an overall structure that defines personalized learning processes. Learning schemas are reconfigurable to match the dynamic changes in learning patterns within a given learning experience. We represent a learning schema as a statechart, which is appropriate for modeling processes such as a learning process. Learning states are run-time reflections of learning patterns. As shown in Figure 5, a statechart is made up of states and transitions. States can be initial, end, basic, or compound. A basic state (representing in this paper a learning task) corresponds to an invocation of a learning service operation. Hence, patterns specify learning services and the service operations implement the pattern's learning tasks. Multiple operations may be invoked within a learning pattern, and several learning tasks may be invoked across learning patterns of a schema. Candidate learning services are selected based on their operations, which match a competency's functional requirements specified in a learning schema. A further selection among matching tasks is based on non-functional attributes such as QoS (Quality of Service) parameters or learning constraints to guide the matching process. Compound states in learning schemas provide a mechanism for nesting one or several statecharts inside a larger statecharts as shown in Figure 5. We use this abstraction to represent learning patterns as learning sub-processes within an overall learning process. This modeling technique facilitates dynamic transitions across learning states in a specific learning dimension, which may occur during a learning process. There are two types of compound states: OR and AND. An OR state contains single statecharts which represent alternative learning tasks, whereas AND states represent concurrent tasks separated by dashed line in Figure 5, which have to take place.

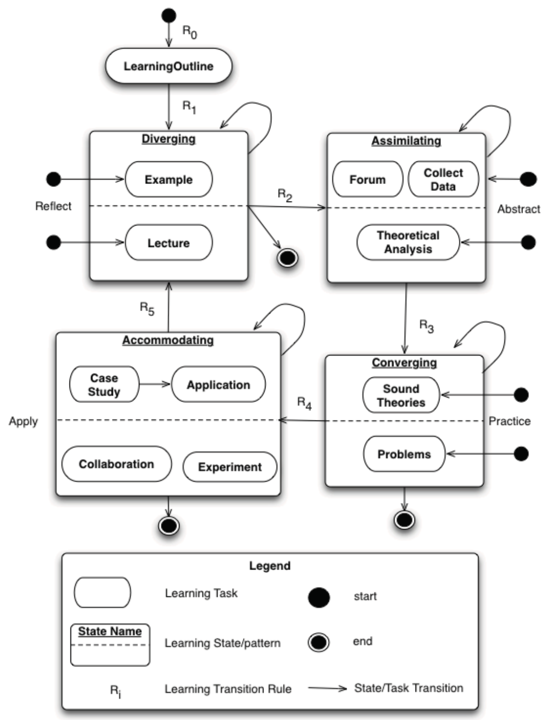


Figure 5. Learning Schema

Figure 5 presents an illustration of a simplified learning schema as a statechart diagram for a particular learning domain subject, which content have been designed. The elaboration of learning schemas may be devised by a pedagogue, in collaboration with the domain expert, or ideally by a domain-specific pedagogue, who could be seen as a senior domain expert with substantial accumulated experience in the subject instruction. In the example shown in Figure 5, learning may start from an overall outliner or from other learning unit instances. The closed circle shows the entry points leading to an initial state of a learning schema. The outliner task reveals the topical list of units modeled by this learning schema. The outliner task is followed by a transition to a Diverging pattern, where the learner may view hands-on examples concurrently with a focused lecture presentation. The learner may remain in the Diverging state for subsequent learning units (hence the loop at the compound box corner), or move to a new state. A transition to a new learning state is triggered by a condition and guided by a policy rule.

In this particular learning schema, the pedagogue advocates possible entry and exit points to fulfill the instruction outcomes. The bordered circle represents final states in the learning schema. For example, Diverging state may complete instruction requirements. However, assimilating state must be followed by converging state across a given learning unit to claim learning completeness in the subject matter, for which the schema in Figure 5 is advocated. Similarly, Accommodating state does not have an entry point (i.e. in this example, it cannot be the initial state). Hence, the learning schema is a learning guide rather than purely preferential style modeler.

Initially, learning schemas are designed and stored. A request for learning identifies a schema model. At run-time, matching learning services are matched to learning tasks in the schema. A coordinator agent sends the learning resources returned by the learning task to the context service along with the learning task policy. Learning reconfiguration is initiated by the learner context. Context data accompanies the reconfiguration event notification. The context-providing service verifies context data against learning-task post-conditions and updates the learner's (LIP) record of competencies accordingly. The next learning service invocation moves learner to a new state based on a schema of patterns description. If all patterns are exhausted or if learning services of the new pattern are unavailable, a new schema request is made.

V. Prototype Implementation

The prototype is implemented in Java on top of a common service registry, which supplies the learning schema as well as the learning service specifications. We used standard Web technologies such as XML, SOAP, WSDL and UDDI (Universal Description, Discovery, and Integration). Figure 6 shows of the prototype featuring the architecture of learning services as separate modules of objects. Learning Factory module generates a composite learning service to map a learning pattern specification and produces requested learning objects. Knowledge Factory module returns an XML specification of the learning schema, while the event-driven Context Factory module captures conditions for adaptations and triggers the reconfiguration process. Although simplistic, the prototype implementation is a proof of concept and a toolkit for usability evaluation. These three modules are further illustrated in Figure 6.

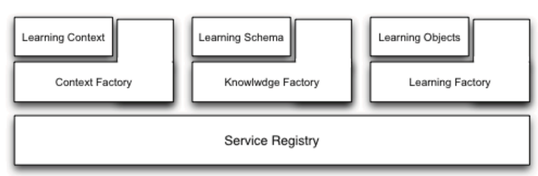
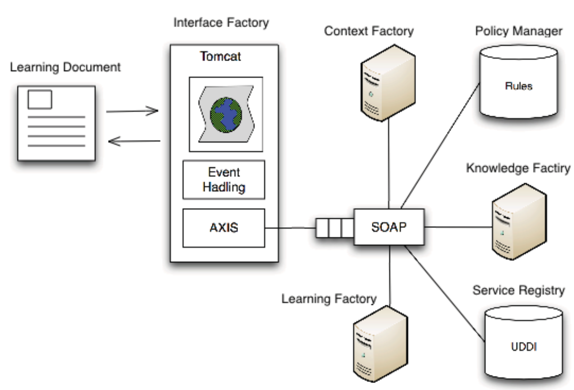


Figure 6. System Architecture

Services are deployed using Apache Axis. Apache Tomcat is used as a Web server where Apache Axis is deployed. Each service has a deployment descriptor that includes the unique identifies of the Java class to be invoked as well as the operations in the class that are available to clients. Learning Factory module uses a learning service registry, which is bound to learning objects repository. The service registry also includes a discovery and invocation facility implemented as SOAP calls (Figure 7). Learning services are simply used as a gateway to learning objects and may offer enhanced operations to deal with a learning object. When a learning service registers with a discovery engine, a UDDI SOAP request containing the service description in WSDL is sent to the UDDI registry. A learning service factory may deliver composite services from existing basic services in UDDI (for e.g. a case study followed by a collaborative project to match the Accommodating pattern description). The knowledge factory module accesses learning schemas stored in the UDDI as a tModels. tModel is a standard specification utility to represent a service type (a generic representation of a registered service) in the UDDI registry. Each learning service provider registered with UDDI maps all of its Web services according to a defined list of learning patterns within a schema (as specified in the example of Figure 5). An instructional designer can search the registry's learning schemas to create the enclosed pattern instances. The tModel organizes the service type's information and makes it accessible in the registry database. Each tModel consists of a name, an explanatory description, and a Universal Unique Identifier (UUID) . The tModel name identifies the service, such as, for example, "Computing Lecture" learning task.



Fi gure 7. Process Architecture

VI. CONCLUSION

The paper addresses learning personalization through adaptive patterns. We introduced learning schemas as means to design patterns of learning in a given instructional subject. Learning patterns encapsulate learning tasks, relevant to experiential learning processes, based on Kolb's foundations of learning theory. Learning schema specification use Statecharts and embedded patterns to reflect a learning style during instruction. Transitions across learning styles dictate learning reconfiguration through rules, which represent pedagogical requirements and personal constraints. Several directions could extend the presented work in this paper. First, we are currently building a portal application to enable learning producers at different level to participate in learning integration workflows. We could also export and share the accumulated learning services of advocated patterns to a public repository.

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Consequences of the Declining Interest in Computer Science Studies in Europe

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***Abstract*—Official European statistics of education indicate that the number of students entering tertiary education have significantly increased between 2000 and 2006 [1], and indicate a trend that will continue. However, this increase is not reflected in every field of study; computer science and engineering are among those that have decreased each year, evidence of a decline of interest in following this career on the part of students. As a response to this disturbing fact, this paper aims to identify some of the possible consequences that this trend could produce in Europe. It will highlight the impacts in economic, social, political and pedagogical fields and explain how these segments will be affected if the decline in computer science persists. Supported by previous investigations and official reports, this analysis provides some examples of the problems already produced by the declining interest in computer science in Europe and proposes solutions such as teaching methods and learning strategies to attract more students to this field and therefore limit the negative effects in a near future.**

Keywords-component; Computer Science studies, learning methods, teaching methods

I. Introduction

The official European statistics reflected a low rate in the number of high school students choosing computer science as a career. While the number of students entering university is rising, this field of study represents just 9.9% and decreases each year [1].

Because of this, European countries might be affected by a low number of experts in technology that represents an important stake for industry. In France for example, people spent a total of 7,965 millions of Euros in technology in 2008 [18].

The relationship between the high demand of technology and the decreasing number of experts to support it, leads us to ask the following questions:

- How can Europe justify the decreasing interest in computer science studies when the demand from the technological industries remains stable?
- What are the main reasons that produce this decline in the choice of computer science as a domain of study?
- Is it important for Europe to promote Engineering school?
- What are the consequences of a reduced number of computer science experts in industry and research in Europe?

This paper aims to demonstrate the imbalance between the number of students choosing computer science as a domain of study in relation to the demand in the industry and points out the importance of attracting and retaining students to this field by highlighting the possible consequences that this decrease could produce in different sectors.

As a conclusion, this document will point to some solutions that could be used in order to bring alternatives to these issues and prevent the negative impacts.

II. Related Work

Certain studies are investigating related questions about the number of students enrolled in technology. Some of these studies highlight the fact of the low interest in computer science as part of their results.

In 2009 the Computing Research Association (CRA) remark that the number of undergraduate students majoring in computer science significantly increased [2]. This fact not only creates a concern about the future of technology in Europe, but also sustains the decline of interest in computer science.

A larger investigation by Mahar, J. [3] was dedicated to find strategies to attract women to computer science, expressing their concern about the low number of them in this scientific field. In 2008, the proportion of women opting for scientific and technological studies was lower than the 40% in Europe, concerning computer science as a part of the study [4].

These references affirm that investigating the reasons of this decline is essential in order to understand and control this problem. Some studies agree that the reason why a student does not pick computer science or does not feel attracted by technology as a domain of study is related to the image these careers reflect or to the degree of difficulty that these domains seems to represent: in 2006, a European orientation study suggested that "*The choice of the students is essentially determined because of the image of the professors in the scientific and technological areas and by the content and quality in the discipline*" [4].

Academics thought that vague and erroneous perception begins in high school and that industry could do more to improve the image of jobs and careers in this domain and help identifying a stereotype that has not been clearly identified yet [5].

Nowadays, the real reasons that produce the rejection of computer science as a domain of study is not yet discovered. However, the importance in the number of technology professionals in Europe is determined by the possible consequences that can take place if this decline is not controlled and this is what this paper will emphasize.

III. Population Results and Education Key Statistics in Europe

The official key statistics in Europe, delivered the results of the educational analysis in the European countries [1].

This study leads to understand the declining performance of computer science school in Europe and enclose general conclusions to better understand the importance on the evolution of this field and its consequences in case of failure.

A. *Education Statistics for Europe 2000-2006*

The statistics published in 2008 [1], indicated that the number of students that have access to tertiary education in Europe is increasing in a sustainable way. In other words, the number of students attending university after high school is rising as shown in Figure 1.

Unfortunately the increase in tertiary studies is not reflected in all domains of study. Graduates in science, mathematics and computing have decreased each year as shown in Figure 2 [1], reflecting the lack of motivation of following scientific careers from the part of students.

While analyzing the computer science results it is important to highlight two main concerns:

- Graduates in computer science and engineering are decreasing; while graduates from other fields of study are increasing or remain stable.
- We can presume that there are specific reasons which cause students to reject science, math, computing, manufacturing and engineering.

The declining interest in computer science education surprise the more when they come from developed countries in which an important part of their industries depend on the evolution of technology and constitute a significant change affecting labor demand [19].

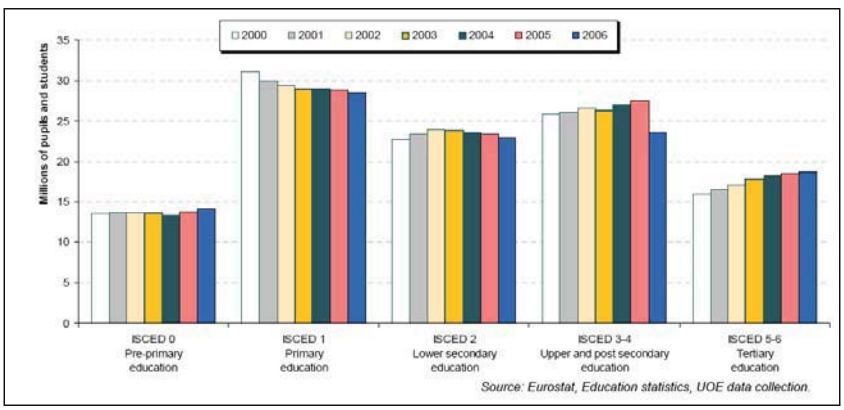

Figure 1. Distribution of tertiary graduates by field of education, EU27, 2000 and 2006, in %

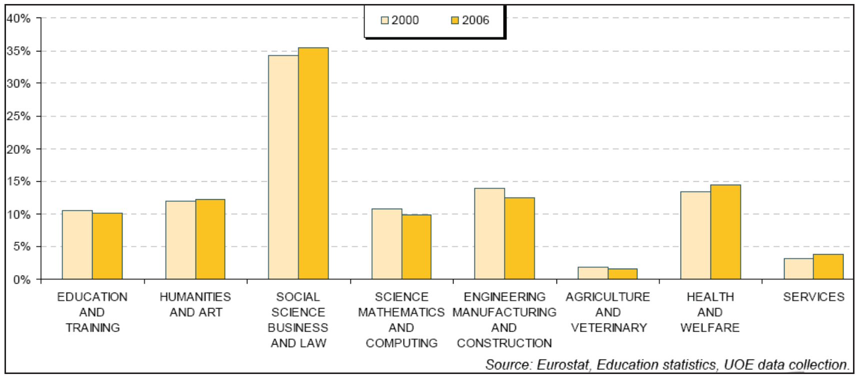

Figure 2. Number of pupils and students by level of education (in millions), EU27, 2000 to 2006

There are other analyses that reflect and confirm the declining interest in computer science, such as the one shown in Figure 3, provided by the Computer Research Policy Association [18]. It illustrates the continuous decrease in computer engineering and computer science graduates from 2001 to 2005.

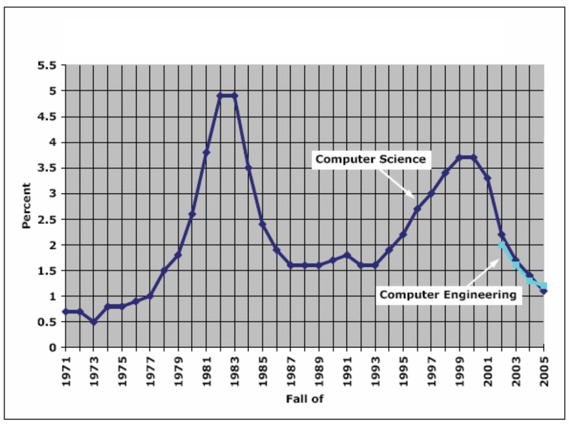

Figure 3. Development of computer engineering and computer science in persentage of university graduates during the last years

These statistics lead us to agree in the fact that the interest in computer science is declining and that this decline may alter and bring consequences in the technological field for European countries.

B. *Analysis and enclose of the situation*

The latest statistics show a reduction in the number of persons studying computer science in university. This decrease represents, as general consequence, the declining number of professionals in this field and thus involved in the development of local technology in Europe.

Other sectors such as the economic, social, political and pedagogical fields will reflect similar consequences. The next section will present the possible impacts of the declining interest in computer science studies in Europe.

IV. CONSEQUENCES OF THE DECLINING INTEREST IN COMPUTER SCIENCE STUDIES IN EUROPE

A. *Economic consequences*

1) A reduction in the number of computer science students will result in a decreaing number of experts in the technology field in the near future

In general, when the stakes of an industry are reduced in number of experts, it will cause an increase in the price of the good or service that these experts provide. The economic model on elasticity shows a comparison between the market price of a product or service and the offer of the same, i.e. less human force with the same demand is equal to a price increase.

The price P of a product is determined by a balance between productions at each price or supply S and the desires of those with purchasing power at each price or demand D. Along with a consequent increase in price and the quantity sold of the product [6]. This theory is quickly highlighted in Figure 4.

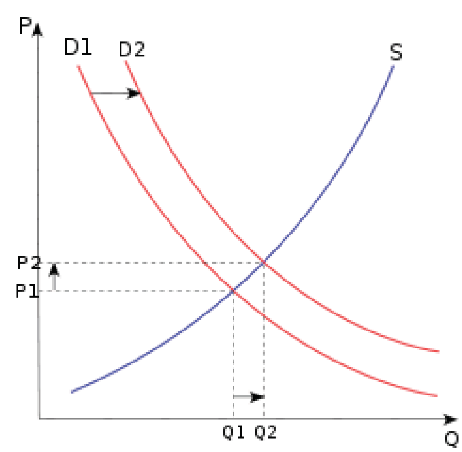

Figure 4. Elasticity of the price of a product

Explained from this point of view the number of students and experts in the technological field is crucial to balance prices and promote the progress of the nation's technology industry, because a low offer in the market of technology represent a more expensive product.

This increase in the price of computing development and the decrease of professionals in the industry can be related to the initiative of the companies that redirect or migrate their labor forces to foreign countries where development is not only as efficient as in Europe, but also where there is a greater available production capacity at a lower cost, e.g. India.

2) A migration in the labor force and technological development to foreign countries

The migration of the technology from a company that can not afford development in its own country is very common these days. Countries will buy the software and programs to other countries willing to maintain the low prices in operative costs.

This fact represents a great opportunity of development for those countries trusting technology as a development strategy. However, a negative impact will take place in the purchasing countries, because this migration can turn out in instability of the industry, due to: the migration of the human force and abolition of actual and future jobs, the reduction in local tax payment and most important, the absent of strategies to manage this impact.

Because of this, predictions of job losses from shifting high-technology work to low-wage nations with strong education systems, like India and China, were greatly exaggerated. As remarked by Lohr, S. 2006, "*The concern is that misplaced pessimism will deter bright young people from pursuing careers in computing, and, in turn, would erode the skills in a field that is crucial to the nation's economic competitiveness"* [7].

B. Social consequences

1) Increase in careers outside math, science, computing, manufacturing and engineering

As we previously understood, the number of university students is rising. This fact also suggests that university students that are not choosing technology as a career are selecting another one. As shown in the previous graphs, careers like business and social science are the ones increasing the most these days [1].

This fact can be related to an increase in the job opportunity needed for negotiating and purchasing technology from other countries. The global increase on the technology demand produces success in management careers such as purchasing and international commerce because the technology that is not being developed in Europe is being purchased from other countries.

This tendency will result in a higher proportion of professionals trained to be managers and businessmen and a lower number of engineers and producers of technology; which is not precisely a negative change, but represents an alteration that needs to be assumed.

2) The need to learn other cultures and languages

Due to the migration of the human resources, there is an increasing need to learn other cultures and languages to succeed in negotiations with other countries.

Nowadays a person speaking several languages has a large number of job offers in Europe thanks to the companies that need interlocutors for their commercial exchanges.

However, the culture and languages of the countries which are involved in technology development are not precisely related to the European. Therefore, Europeans might loose their strengths of speaking English, French and Spanish (more speak languages in Europe and in the world) and became weak when facing the opportunities that are presented to Chinese, Russian and other languages speaking countries [8].

Following this example, we may find a certain number of investigations considering the importance of integrating foreign languages and cultures to European countries, not only in the name of technology development, but also because unique educational modules, courses and programs are being designed and evaluated throughout the Asian region, evidencing issues, challenges, opportunities and initiatives related to the education of technology. [20]

One of the solutions could be to include these languages in the curricula offered to students seeking careers in business. This will permit students to gain opportunities in international job offers and be prepared to affront their professional lives after university. Some studies emphasize the importance of learning other languages to meet this demand and to adopt the economic change that Europe might be affronting [9].

Unfortunately taking as an example the program of study offered to students of one of the most popular careers (economics and management) at one of the best universities in Europe, we can see that the language options are limited to Europeans and neither Chinese nor Japanese, or other language that represent geographical expansion is offered as shown in Figure 5 [10].


semestre 2

Intitulé des UE et des enseignements	CM	TD	ECTS
choix langue			2
Anglais gestion, S2			
Allemand gestion, S2			
Organisation & management			4
Organisation & management			
Bonus langue S2			
Anglais gestion, S2			
Allemand gestion, S2			
Espagnol gestion, S2			2
Activités culturelles S2			
Activités sportives S2			
Volume semestriel par étudiant			30

Figure 5. Sorbonne University, 2nd semester Management Curricula

However in its many international exchanges, European universities are providing educational programs to foreigners, giving them the expertise and knowledge of the European market and enhancing the population that in some years will represent the strongest competition for local professionals.

This fact can be demonstrated by an example: In France the number of Asian students has tripled in five years; as published in its annual report on diplomacy in 2006.

Thus Asians represent the fastest growing group of foreign students highly incentive form the French government [11], however this document specifies as well that only 5% of these foreign students stay in France, while the rest of them return to their countries to work in the field contributing to the migration of the technology development.

By the other hand, the countries producing technology can appreciate a fast progress observed from a positive point of view. Some countries might find in this the occasion to expand their industries and create links with other cultures that will represent an economic profit for them.

C. Political consequences

1) General dissatisfaction causing political instability

The lack of opportunities in a country for a person that has concluded secondary studies can represent a menace to the economy and the stability of the country itself. The information about companies that migrates the development of technology out of Europe might guide us to ask ourselves about the future of thus professionals that might lose their opportunities to work.

Europe is already subject to several aggressive strikes that reflect the dissatisfaction of the local workers due to the migration of the labor force to other countries which is affecting their careers.

For example, the employees of JLG Industries, the world's leading designer, manufacturer and marketer of access equipment, went on strike as a result of a possible delocalization of the labor force. The employees threatened to explode the warehouse if the company did not stop the policy of firing a certain number of people at the end of the year [12].

Another related event was a demonstration organized by students of informatics engineering and other careers related to computer science, who manifested their concern about the lack of job opportunities in the field in Europe [13].

These demonstrations create an environment of insecurity, violence and material damages in Europe that can also harm political image.

2) Modifications in the national curricula

The political influences on education have been rapidly increasing over the past several decades. Recently, the power of the state has been expanding further into the domain of the university. Any curricular changes in teacher education must be planned with an eye toward the state's expected role. This may be the most crucial aspect of technology integration.

Curriculum developers may not be well versed in governmental matters and may have to change the ways they prepare for reform while facing changes in things such as: the budget, the importance to foreign languages and cultures and the political instability. [21]

D. Pedagogic consequences

1) Declining careers in engineering

If the number of graduates in a specific subject is reduced or simply modified, there will be a similar reduction or modification in the number of professors in this discipline. Therefore, the difficulty to find teachers that provide students the knowledge and expertise to develop technology will increase.

The success of computer science is based on the number of experts involved in the same geographic area, the entire development of technology depends on the persons who have the expertise to create and maintain technology because they are capable to create and maintain technology material.

2) Declining investment in the field of study

The fact of reducing the number of computer science students might represent less founds for the development of this educational sector, because institutions in charge of providing money to education will not invest in a career without students. As a catastrophic result this could eventually mean the complete elimination of this career in Europe.

One example of this fact is reflected in the European Commission that will sponsor a large number of contracts directed to technology research in order to the results that the partners conforming this contracts could offer, i.e. the number of publications in collaboration with students and professors. Therefore, with no experts working in the development of technology research, the funds coming from the European Union might be reduced.

V. CONCLUSIONS AND FUTURE WORK

After analyzing the consequences of the declining interest in computer science in Europe, two main conclusions can be appreciated:

A. Increase the number of computer scientist in Europe

The first conclusion refers to the fact that in order to maintain the development of computer science as a career and as the basis of technology in Europe it is necessary to attract and retain human talent in this field.

As a strategy to this matter, a future work can be directed to identify the reasons why a student does not feel the motivation to follow computer science studies as a career and to create methods that attract and retain people in this domain of study.

As mentioned previously, some studies blame the negative image this career reflects while observing the professionals working in this field [5].

Other analysis demonstrate that preventing young students from using technology in an early age might psychologically affect a child and cause him to reject this discipline his entire life. Parents forbid children to touch expensive equipment (that could be attractive to them in the first place), such as computers and televisions etc. and give them the wrong impression of being incapable to operate them and impede the development of their technological skills [16].

Other programs have directed their strategies to attract women to these scientific domains. The development of such strategies has made it possible to attract undergraduate students historically not enrolled in computing courses and therefore attract students to this field [15].

B. *Adopting the changes that computer science is affronting*

As specified before, a general recommendation to adopt the technological raising in other countries is necessary. The fact of learning other languages, expanding markets and modifying teaching/learning curricula was mentioned as a technique to affront the consequences of the migration of computer science and gain advantages in the international market.

Other initiatives have already launched strategies targeting a more specific area; they create teaching and learning methods to enhance e-learning and support students with the help of information technologies such as "Effective video clips for Web-based language learning" [14]. This study affirms that the opportunity of providing new technological features to existing teaching methods will help attracting users and students to the technological field.

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Adjunct Enterprise Professors in the European Higher Education Area

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Abstract—**The PAVEs Program (Profesores Asociados Vinculados a Empresa – Adjunct Enterprise Professors) of the University of Valladolid allows enterprises to offer a set of optional subjects dealing with the technological knowledge necessary for their operation. These subjects are not only very attractive for the students, as they are given the chance to get an insight of the world that will host them as employees in the future, but also could be studied to extract lessons about the future European Higher Education Area (EHEA). This work presents the PAVEs program, the lessons learned that could be applied to the plan adaptation to the EHEA, and how the PAVEs subjects could be better integrated with ordinary subjects in the upcoming EHEA.**

Keywords- ECTS; Adjunct Enterprise Professors; Practical Education; Learning Technology; EHEA.

I. Introduction

The PAVEs Program (Profesores Asociados Vinculados a Empresas – Adjunct Enterprise Professors) is aimed at bridging the gap in the educational plane between the industry and the academia [1]. This program represents a unique collaboration initiative in the Spanish landscape, and has revealed itself as a very efficient tool for the students of technical degrees in the University of Valladolid.

Traditional collaboration among industry and academia has been focused on research activities, either having universities as consultants or partners for research, development and innovation activities. There is an extensive literature describing this, for instance [2] and [3]. However, collaboration in the educational plane has not been typically addressed.

The industry has a very wide spectrum of very specific skills which are necessary for each of the activities carried out in the different areas. Traditional academic programs are limited in time, and priorities have to be assigned so all the basics of the profession can be taught. The idea behind the PAVEs program is to take advantage of some of this industrial knowledge and bring it to the University students, so they can have a first approach to the details of some of the real industrial activities and the necessary skills to perform them) that they will carry out during their professional lives, effectively bridging the transition from student to apprentice. The teacher of a PAVEs subject is an industry professional acting as Adjunct Enterprise Professor, classes could be conducted within that enterprise premises, and although students do not perform any practical industrial work during these classes, they learn the skills, techniques and knowledge to do so.

Therefore, when students obtain their degrees, they have already some contact with the skills, habits and best practices required in the industry, which are not always teachable by professors which have been involved in academic spheres for years.

The PAVEs program has been active since 2001, when the University of Valladolid and the Regional Government (with the aid of the Spanish Ministry of education and the Spanish Ministry of Economy) reached an agreement to integrate Adjunct Professors from the industry sector into de University hierarchy. This agreement, with an initial duration of 2 years, has been renewed several times, and a total of 50 professors coming from the technical and engineering areas are involved.

As the PAVEs program has had an eminently practical approach and has tried to avoid traditional unidirectional learning methods, it can be considered a great information source to extract experimental conclusions about the new orientation of the education system in the European Higher Education Area. This information could be used for instance to drive the design of educational programs on the different subjects for the future convergent European framework.

The PAVEs program could be considered an innovative experience with very similar aims to those of the EHEA (European Higher Education Area), in particular, the practical approach and the compatibility with the ECTS (European Credit Transfer System) credit systems, based on the students' workload required to reach the objectives of the subject instead of just hours attending classes. In this sense, the PAVEs program aims in the right direction to foster the implantation of ECTS credits, focusing directly on the students' efforts to learn the subject and letting the student play the main role in his own education.

II. Telefónica I+D in the Adjunct Enterprise Proffesor Program

Telefónica I+D, the Research and Development branch of Telefónica, the Spanish telco operator, is one of the most active companies in the PAVEs program of the University of

Valladolid, through its nearby premises in the Boecillo Technological Area (Parque Tecnológico de Boecillo). It has been offering a wide array of subjects inside the program for years with very good results [4].

For academic year 2009-2010, Telefónica I+D offers a total of seven different subjects, covering several areas like Multimedia, Next-Generation Networks, Web Programming and Service Provision [5].

The subject "Innovación: Servicios" (Innovation: Services) is a transversal course dealing with how the Research – Development – Innovation cycle is implemented in the enterprise. A first, generic block of the subject presents a description of the R+D+i cycle, its implications in the industry, and best practices, including the funnel diagram, typical procedures, publications and patents. The second content block presents the application of these concepts to several specific areas, including communications, mobility, digital home, etc.

The subject "Servicios Avanzados de Apoyo a Aplicaciones Telemáticas" (Advanced Services for Telematic Application Support) presents the innovative low-level services introduced by telco operators to support next-generation converged applications. Specifically, context-aware and location services, support for Mobile Ad-hoc Networks (MANET) and frameworks for Next Generation Network management.

The subject "Desarrollo de Aplicaciones Orientadas a Internet" (Development of Internet-oriented Applications) is aimed at preparing the students with the specific programming skills that the ICT (Information and Communication Technologies) industry is employing in the state of the art trends in the internet, including Web 2.0 and Web 3.0, Web Services, Service Mashups, RIA (Rich Internet Applications) [6]. This subject teaches how to develop a dynamic Web application accessing a database using Java as a programming language. Web servers, Development tools and environments, Web applications architectures, Servlets, JSP, JDBC, iBatis and AJAX are the technologies to be explained during this course.

The subject "Desarrollo de Componentes y Servicios en .NET" (Component and Service Development in .NET) aims at teaching how to create applications for the Windows operating system, ranging from traditional, simple ones like Microsoft Office expansions to more sophisticated ones taking advantage of innovative resources, such as N-layer applications or multi-touch interfaces. Technologies to be investigated within this course include .NET Framework v3.5, SOAP Web Services, ASP .NET, Windows Form, WPF, Silverlight, Windows Azure, Windows Surface and Windows 7.

The subject "Servicios Móviles sobre IP y de Tercera Generación" (IP-based and Third Generation Mobile Services) aims at providing an insight on how service development for mobile environments aimed at end users is carried out using the latest technologies. State of the art technologies in distributed mobile applications are presented, and popular environments such as iPhone and Android are investigated. Additionally, the innovative Scrum development methodology is studied, teaching the studies how to conduct team work and application development following its principles, and how it is employed in real world enterprises.

The subject "Fixed-Mobile Service Convergence on IMS" aims at teaching students how the converged Internet of the future is being shaped, how telco operators' infrastructures are changing to adopt IMS (IP Multimedia Subsystem) [7], and how the Quality of Experience concept is applied to network design. With an eminent practical approach, this subject will train students in several areas related to IMS and convergence, including IMS Testbed Installation and configuration; Femto-cells and convergent technologies; SIP and SIP-SIMPLE practical analysis with network analyzers; multimedia convergent service creation based on SIP (with session transfer); Quality of Experience model definition for messaging, interactive or streaming services; and studies on the technologies enabling the Internet of the future.

The subject "Redes de Cuarta Generación, Interconexión y Gestión de Red" (Fourth Generation Networks, Interconnection and Network Management) aims at introducing the fourth generation of mobile communications to the students, and teach them how implementation and management of fourth generation systems is carried out. The course is focused in the feature of heterogeneous 4G networks and Internet access protocols in high mobility environments, and includes practices on designing a management system for 4G networks.

III. Integration Within Official Degrees in the EHEA

A good integration of the PAVEs subjects into the programs of the official degrees, and together with the ordinary subjects is a key factor for its success. There is a risk that due to the fundamental differences in the matters covered by the PAVEs and the ordinary subjects, students can develop the perception that they account for two completely different, and even competing, realities. It is necessary to counter this risk inducing the idea that they are actually complementary, and that the same knowledge acquired in more theoretical subjects is actually applied in the industry activities shown in the PAVEs.

A very good approach to foster a coherent integration of both worlds is to actually create links among PAVEs and ordinary subjects. As the EHEA promotes a bigger presence of practical activities, ordinary subjects are also increasing the amount of this kind of practical contents. The approach suggested in this work is to take advantage of this fact, and interpret PAVEs as a kind of practical modules that can be optionally "plugged" with ordinary subjects in order to substitute or complement the ordinary practices.

This allows an intimate contact among the ordinary subjects and the PAVEs, and a direct, easy linking of the theoretical concepts with the industrial, practical knowledge. This brings a twofold benefit. First, the theoretical concepts taught give a good basis to understand the fundamentals of the technologies seen in action during the PAVEs. And second, the conceptual knowledge is better understood, as real world applications are presented as an example of the usefulness of the theory.

However, these links have to be carried out in a subtle manner, so as ordinary subjects are not interfered, hijacked or distorted by the industrial contents. University professors have to keep their workload and official study programs have to be fulfilled according to the defined specifications.

There are some options to implement this link among the different subjects, which have been actually tested within real experiences in the University of Valladolid. In the Polytechnic School [8], practical credits of degree modules are taught by PAVEs professors. But in subjects with very large student bases this approach could be difficult to follow, as industrial premises are not always adapted to host a big number of practicing students.

For these cases, another approach is suggested, which has been named "subject association". This approach implies a link between a specific ordinary subject and a specific PAVEs subject. The ordinary subject is a complete subject, including all the necessary theoretical and practical concepts, and the PAVEs subject is an industrial application of the concepts explained in the ordinary subject. Students are then given the chance to optionally take the PAVEs as a substitution of the practical credits of the ordinary subject.

An example of this subject association was carried out in the University of Valladolid [9]. The *Projects* subject, which deals with the project management discipline, is particularly suitable for an industrial approach in the practical credits. As a standalone subject, the teacher usually has to present use cases to illustrate the application of the management tools studied, and the nearer they are to real experiences, the better the subtleties of the problems encountered in the real world are captured. Therefore, through PAVEs subjects it is possible to offer real examples of project management to the students, specifically in this pilot *Voice over IP* and *Development of Internet oriented applications* were the PAVEs subjects which could substitute the practical credits of the ordinary subject.

The experiences carried out within the PAVEs program show that the achievements obtained are in line with the objectives of the EHEA. This means that the novel methodologies fostered by the EHEA are pointing in the right direction, and that the implementation of the PAVEs subjects could be used as a kind of guide to help modifying the study programs and adapt them to the EHEA.

Specifically, the PAVEs program has been monitored yearly since its beginning by conducting a series of surveys among the students implied in order to extract conclusions on the satisfaction level. These surveys have shown that students of PAVEs subjects are very satisfied with the experience, mainly because of the following reasons:

- Interesting and attractive contents, which depart a little from the traditional academic approach followed by ordinary subjects, and are usually focused on state of the art technologies instead of the basics and generalities that often form the core of ordinary study plans.
- Approach to a real world company, opening a whole new world of experiences, methodologies and procedures. The direct contact with this new world induces a bigger motivation and interest in the students.
- For students, the University often becomes a kind of bubble, with its own idiosyncrasy, which prevents them from actually experiencing the real world. This sometimes translates in ignorance about the kind of professional work that they will be performing after leaving the academia, and in the fact that very few students actually have clear ideas about their labor objectives in the long term, and how to orient their careers accordingly. Being in contact with the industry helps them to get an insight on the specificities of enterprises and the real work that they will be performing in the future, also helping in many cases to take personal decisions about the kind of jobs that they will pursue.
- The focus on practical tasks helps diversifying the kind of activities that a student has to ordinarily perform. This results in an increased interest and in fighting some of the student's negative feelings about the University and clarifying doubts about the actual usefulness of the studying activity. This is reflected in the fact that many students recognize PAVEs subjects as one of the most interesting activities within their degree programs and continue taking PAVEs courses during the following years.

The philosophy behind PAVEs subjects is quite in line with the new paradigm driving the EHEA. Specifically [10],

- The contents are mainly practical.
- Reduced student groups foster teacher-student interaction, while at the same time adapt better to the industrial premises which are often not adapted to big groups.
- Student-centric learning, meaning that the teacher acts like a guidance to allow the students "discover" the knowledge by themselves.
- Emphasis in group and collective work, sometimes even mimicking real team structure of the enterprise.
- Focus on industry-specific skills.

However, there is still some work to do in order to achieve a complete integration of the PAVEs program into the EHEA, mainly:

- Study of subject structure according to the formal conventions of the EHEA, namely distinction between on-site and off-site tasks, and a proper workload distribution among those tasks.
- Usage of English language.
- Introduction of transversal activities to foster the acquisition of side personal skills, including document search, organization and development, budget and team management, negotiation, etc.

IV. CONCLUSIONS

The PAVEs program of the University of Valladolid has revealed itself as one of the most attractive and innovative initiatives related to the courses offered to the students. Not only it comprises specialized and practical contents that are not frequently found in ordinary subjects, but also gives the chance to students to get in contact with the enterprises, a world that is mostly unknown for them, that they will have to join one day and that remains strange. Through this contact, students get an insight at the environment and practices in this strange world.

Additionally, some of the main characteristics of the PAVEs program have made it a very interesting experience to get some lessons for the adaptation of courses to the upcoming EHEA. The main driving philosophy, the idea that the practical contents should have a prominence and that the students should be playing the key role in their own education, is shared among the two initiatives. This means that while PAVEs subjects do not still fully conform to the conventions of the EHEA, they are a good value for extracting conclusions about the new orientation of the academic degrees.

Finally, letting the industries permeate somehow the University education may initially raise some concerns related to the influence and control they may exercise. Therefore it is worth mentioning that within the PAVEs program, the independence of the University as an academic institution is always guaranteed. PAVEs subject complete education programs introducing side knowledge into them as optional courses, never substituting the traditional base subjects.

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Competence certification as a driver for professional development: A IT-related case-study

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Abstract— **Human resource managers have typically used certifications as an indicator of an individual skill set suitability for a specific position. Certifications act as a signal to hiring managers that a job candidate has achieved a level of knowledge and skill necessary to perform in a particular job role. In the IT (Information Technologies) sector, a recent study sought to determine if human resource managers (HR) and IT professionals perceived certifications differently in the context of the hiring process [7]. The purpose of this exploratory case study was to determine how IT professionals perceive certification programs as a professional training alternative, when compared with more traditional education settings, and the kind of effect the effective participation in one of the programs has in that judgment. The data for this exploratory study was gathered from a 58 employee sample of a Portuguese-based multinational software engineering company. An experimental *Competence Certification Effects Scale* (CCES) was used, and after a consistency analysis, the original 22 items were reduced to 17, grouped in a 4-factor structure: "*Intrinsic Value*"; "*Certification as Training*"; "*Career Management*"; and "*Effort Trade-off*". Cronbach`s alphas were .81, .81, .83, and .81, respectively.**

In short, the findings of the study indicate that there is a significant difference in the perceived usefulness of a certification, if an employee participates or not in a dedicated certification program. This difference is more significant in more senior, management-related roles, as for junior engineers that don't participate in a certification program, this participation isn`t seen as a professional development anchor or a valid education driver. The paper presents and discusses the study`s main results in points III to V, after describing methodological aspects and the underlying theoretical framework.

Keywords-component; Competency certification; Self-directed learning; Career management

I. Learning and training in the contemporary work space: The IT sector case.

In present contemporary workspaces, punctuated by severe competition pressures, the accelerated incorporation of technology in work processes, and the prevalence of high paced information exchanges and commercial trades in a worldwide scale, the individual, group and organizational differentiation that can co-exist in work organizations is a fundamental attribute in their current social development consolidation paths. Having this setting in mind, the certification of professional competences represent one of the available alternatives to adjust the workforce to flexible work processes demands, also responding to social and labour rights compliance needs ([1], [7], [14]).

It is fairly documented that the contemporary society is characterized by rapid developing and ever-changing political, social, economical, technological and environmental situations. Consequently, living in the 21st century is making great demands on its members in virtually every aspect of their lives. Technology subjects and the engineering domain are, in particular, affected by this situation. As a result of this, educational approaches have changed over the last century from remedial repetitive learning to today's learning, which focuses on acquiring an understanding of how to become more independent in the learning process [3]. Learning is no longer concentrated mainly in the first stages of human life through formal education and specific training in business, but it becomes a day-by-day routine over a individual's life cycle. This situation requires new forms and channels to animate learning processes.

Considering the set of institutional devices that is possible to trigger or implement to get a enriched adjustment of each worker to a particular job role, professional training currently occupies a prominent role, as it represents a strategic process to adapt the knowledge profile of a company`s workforce. Nowadays, corporate training and education services correspond to a fundamental regulation tool in the competence development domain, and must be understood not only as an economical or organizational redesign resource, but also as a personal change opportunity, in the sense that provides a setting to change a worker`s behaviour, beliefs and knowledge pool. In fact, according with Tajfel`s social identity theory [17], it`s reasonable to suppose that professional training practices act in order to enable positive social identity dispositions and a satisfactory self-image, as a training program participation has a positive effect in terms of self-esteem, in those that are enrolled and make part of it.

The current value that his given to learning processes in the workplace, has a different origin than the seminal 19th century goals that justified the emergence of skill enhancement measures, has a way to enable the industrial labour force cultural emancipation; currently, continuous learning and skill development are closed linked to productivity, quality and aggressive competition needs, that highlight the workplace as one of the most relevant social locus to support (formal and informal) learning processes. Authors like Lave and Wenger [12], and Billett [3] consistently state that a workspace, whatever its context or specificity, is the ideal social milieu to promote individual and group-related learning and social integration, due to the tight connection that it promotes, by articulating the theorical "world" with professional, concrete practices.

In this sense, it`s understood that formal education and training (and certification) contribute to only a small proportion of learning at work [10]; developing a understanding of situations, colleagues, the work unit and the organisation are examples where learning primarily occurs while working, rather than in a formal educational setting [3]. Similarly, much learning that occurs at work depends upon peer interaction and knowledge sharing, and the use of knowledge resources outside formal education and training settings.

The possibility of each individual become a co-creator of his/her education biography through the lifespan, is a tendency that reinforces the idea of multiplication and co-existence of multi-level learning locus in contemporary work organizations. When employee development budgets are being scrutinized, blending learning into the way work is done is more important than ever. Organizations need their learning approach to be more innovative and efficient than ever before - to make the most of technology advancement, reach geographically dispersed learners, and meet budget requirements. If what people need to learn is defined by organizational business priorities, new learner-centered mediums integrate this learning into the workflow.

Self-paced learning mediums depend of several individual cognitive attributes, such as self-management and learner control, self-direction and motivational dispositions [6], and particular development needs of each employee, with little or none external supervision. With this medium, individual motivation to engage in learning tasks and the external encouragement of their fulfilment, are primary drivers that enlarge education domains to virtual, technology-driven immaterial learning contexts, changing the way learning processes are seen, making them more accessible, dynamic and flexible [4]. Through technology and, in particular, web-based developments, it is easier to communicate, share ideas and specific knowledge.

Despite these changes, it`s rather relevant to teach people how to use the technology to have a social learning experience and collaborate in knowledge sharing, and, in a organizational setting, to learn how to mediate a process that has as drivers subjective and relational features. To some extent, learners need to learn how to capitalize knowledge on the social milieu, by learning to learn with and from others, and managers are asked to learn to mediate others' learning, not only for their sake but for what that will teach oneself, and learning to contribute to the learning of a collective.

Duderstadt [9] suggests that we are experiencing a shift from just-in-case to just-in-time to just-for you education, equivalent to a shift from synchronous, classroom-based instruction to asynchronous e-learning, to ubiquitous learning opportunities. This author uses ubiquitous learning to refer to a culture of learning in which people are continually surrounded by, immersed in, and absorbed in learning experiences; a necessity in a world driven by an expanding knowledge base and need for continuous learning.

Organizational training processes goals cannot be resumed to merely instrumental, business-driven targets that, despite the legitimacy, erode the emancipation and development potential associated with that processes implementation. Training practices are valued by stakeholders as inclusive strategies, a symptom of a organization`s maturity and concern to address its labour force particular skills and career development needs.

Promoting an autonomy and learner-centered culture opens the possibility for a organization to experiment different strategies for addressing skills adjustment needs, allowing individual initiatives in the definition of career and development projects. Self-paced instruction and computer-based training, training delivery forms that can be triggered within a anytime, anyplace approach, have been gaining visibility as valid alternatives to conventional instructor-led classroom training.

In this context, the particular question of how to validate new skills and knowledge informally build is frequently raised. Credentials and certification programs, used by HR managers as indicators of an individual skill set suitability for a specific position, currently are in the spotlight as career and skill development anchors [2]. The participation in certification program is recognized as faster, cheaper, and more focused education alternatives, yet, many questions arise around the issue of how occupation specific credentials compare with the more traditional educational qualifications.

According to Bird [4], a changing economy and job market places a higher value on knowledge and applied skills. In the IT sector, a domain where credentials and certifications are increasingly being valued, certifications act as a signal to hiring managers that a job candidate has achieved a level of knowledge and skill necessary to perform in a particular IT job role. The findings of a recent study [7] indicated that managers placed a greater emphasis on certifications when hiring for IT related positions. The question of whether certified individuals are better able to perform in an IT job-role, than non-certified individuals becomes relevant in the hiring process [1].

Existing theory provides a strong conceptual framework for examining the role of industry credentials in recruitment for IT positions. Qualifications and credentials have long served as signals for organizations. Signaling theory, originally developed in economics, suggests that employers require information (observable characteristics and attributes of an individual) about potential employees to determine the job positions and salaries offered to the employee ([15]; [14]). Some observable attributes of individuals are unalterable (e.g., age, gender), while others are subject to change usually at the initiative of the individual (e.g., education). Spence [15] referred to these alterable attributes as signals.

Presently, any individual can claim to be an "expert" in a particular process, subject matter or technology. But for employers, quality assurance is vitally important in this context. Since employers have incomplete information about the knowledge, skills, and abilities of applicants, they use qualifications and credentials as signals for making inferences about missing information in determining the likely suitability of prospective employees [14]. The value that organizations place on different qualifications can also act as a signal to applicants. For example, organizational preferences for either externally validated assessment of skills (IT or management certifications, for instance) or more traditional college qualifications provide applicants with information about what it would be like to be a member of that organization, and what type of skills and knowledge it values.

The demand for workers with specialized skills has placed a considerable pressure on traditional educational strategies to provide a qualified and sustainable workforce. In the IT sector, certifications have become a standard precursor to employment for many IT job roles serving as a "work ready" indication to HR managers, that specific precursory knowledge or competencies have been met.

Despite the growth in the use of these programs as institutional training alternatives, their success isn`t linearly guaranteed, as they depend, in a considerable scale, of the applicants` commitment to learn, their ability to control and pace learning activities, and the existence of external support and encouragement. These variables are particularly relevant if the certification programs success largely depend of self-paced learning efforts [6], a potentially conflictive context where learning activities can be seen by applicants as a result of personal investment, and not as a result of a corporate learning policy.

II. METHOD

The relevance of this study is associated with the raising importance of learner and individual-centered learning processes, and the diversification of training strategies and learning *foci* that can co-exist in contemporary workspaces; in particular, the study is centered in the growth of competency certification programs in the IT sector, and in the way these programs and concrete participations on them are perceived by certification applicants.

In terms of analytical focus, a case-study research strategy was applied in a portuguese multinational IT-based company, whose activity combines expertise in several engineering disciplines, enabling software solutions for demanding and crosscutting problems. The company's engagement model covers the whole software life-cycle, from planning and analysis, to design, development, integration, testing and maintenance, and focus on enterprise oriented solutions for different markets. This organisation fosters constant innovation and the use of training and learning management top notch practices, providing all workers the best possible training for a large range of job roles. As the job requirements are becoming increasingly specialised, the implementation of certification programs in technical, managerial and language skills domains has become, during the past years, a relevant training instrument.

These programs are supported by practical seminars, informal peer-based knowledge sharing, and, to some extent, self-directed learning that is encouraged by the organization`s team and area managers. In the past two years, more than 70 certifications were obtained, but, despite these success evidences, this exploratory case study aims to determine how IT professionals of this particular organization perceive certification programs as a professional training alternative, when compared with more traditional education settings, the personal investment implied in the participation in one of this programs, and the kind of effect the effective participation in one of the programs has in the global judgment made about its efficiency and relevance.

A. Participants

The data for this exploratory study was gathered from a 58 employee sample of a portuguese based multinational software engineering company. An experimental *Competence Certification Effects Scale* (CCES) was designed and applied using a web-based questionnaire management tool.

TABLE I. CASE STUDY PARTICIPANTS: GENERAL DEMOGRAPHIC CHARACTERISTICS (N=58)

		n	%
Gender	M	54	93.1
	F	4	6.9
Age	24-29	29	50.0
	30-35	22	37.9
	36-43	7	12.1
Participation in a certification program (past 12 months)	Yes	31	53.4
	No	27	46.6
Job role	Junior Engineer	26	44.8
	Project Engineer	11	19.0
	Senior Engineer	2	3.4
	Engineering Manager	5	8.6
	Business Developer	1	1.7
	Project Manager	13	22.4
Years worked in company	≤ 1 year	19	33.8
	2 a 3 years	25	43.1
	4 a 5 years	10	17.2
	6 a 7 years	1	1.7
	8 a 9 years	1	1.7
	10 a 11 years	1	1.7
Total		*58*	*100*

The primary criteria used to identify the study participants, was the effective participation in a competency certification program in the 12 months prior to the scale`s application, or a planned participation in the 12 months period subsequent to the

CCES application. The participants` age varies between 24 and 43 years old, and as is presented in *Table 1*, there is a larger, but non-significant, percentage of study participants that effectively engaged in a certification program (53,4%). *Table 1* also shows that 26 of the 5 study participants occupy junior engineer roles, and 77% of the participants work in the company considered in the study for 1 to 3 years.

B. Procedure

This study`s deployment implied the request for participation of a group of employees, according the criteria described in the previous topic. 60% of the enrolled study employees replied to the participation request, and 58 scale answers were gathered and considered in the analysis procedures. The participation in the study was voluntary. According with the research questions and hypothesis – the concrete participation in a certification program has a positive modulation effect, in the way these programs are perceived as relevant skills and career development anchors –, a 22 Likert-like items exploratory scale was designed, with 5 answer options available for each item [1], ranging between total disagreement (1) and total agreement (5). The original *Competence Certification Effects Scale* (CCES) had 22 items, but after a communalities analysis (h^2) (see *Table 2*), five of the original items pool (items CCES_1, CCES_2, CCES_12, CCES_14 e CCES_22) didn`t reach the required cut point, 0.40 [16], and due to this they were removed form the analysis procedures.

The items used in the scale were inspired or adapted of previous learning and competency certification-related studies of Lave and Wenger [12], Candy [6], Rainbird [13], Cegielski [7], Souza and Luciano [14], and Billett [3]. To compile statistical measures, SPSS 17.0 was used as support tool. In order to explore the proposed scale underlying dimensions a exploratory factorial analysis was used; factor extraction used the principal components method and orthogonal *varimax* rotation. The adequacy of the factorial analysis was evaluated by means of the Kaiser-Meyer-Olkin test and Bartlett's sphericity test.

The CCES 17 final items inter-correlations matrix was subjected to analysis, and a 4-factor solution was found, with a total explained variance of 65.48%; the underlying sense of each factor was interpreted, and the scores of the first factor (F1: ValInt) were used as a indicator of a certification perceived intrinsic value, the second one was related with the value of a certification program as a institutional training option (F2: ValCertTrain), the scores of the third were related with career management effects (F3: CertGestCarr), and the fourth linked with the investment and effort trade-off (F4: EffortTrade) implied in a certification program participation. In order to identify group differences, *t* and *one-way* ANOVA tests were made, according with the groups formed by the independent variables *certification program participation*, *age* and *job role*, variables with a relevant effect in the explanation of the differences that were found. The adopted level of statistical significance was $p \leq 0.05$.

[1] Some inverted items were included in the exploratory study scale (CCES).

III. Results

The standardised coefficient alpha was used to estimate internal consistency for the CCES final scale and the results obtained for the 4-factor structure solution – "*Certification intrinsic value*"; "*Certification as training*"; "*Career management effects*"; and "*Effort trade-off*" – were .81, .81, .83, and .81, respectively. All items were positively correlated with the scale with the target item removed, when their correlations were examined by standard alpha coefficient analyses, a result that confirmed the relevance of the scale`s final 17 items.

The adequacy of the factorial analysis was evaluated by means of the Kaiser-Meyer-Olkin test and Bartlett's sphericity test. The KMO test score (KMO = .807 [≥ .60]) validates data adequacy to take the factorial analysis solution in consideration; Bartlett's sphericity test is also statistically significant (χ^2 =590.714 p = .000 [≤ .05]). After a communalities analysis (h^2) (see *Table 2*), five of the 22 original items pool (items CCES_1, CCES_2, CCES_12, CCES_14 e CCES_22) didn`t reach the required cut point, 0.40 [16], and due to this they were removed form the analysis procedures.

In order to explore the proposed scale underlying dimensions a exploratory factorial analysis was used; factor extraction used the principal components method and orthogonal *varimax* rotation, with factor retention for factors with *eigenvalues* greater than 1. The analytical procedures revealed a 4-factor solution with an *eigenvalue* greater than 1 ([5]; [11]), accounting for 65.48% of total explained measure data variance. Cattell`s screen test corroborated this observation. *Table 2* shows the 4-factor solution found for the measures, the scale items and correspondent communalities. Significant loadings, superior to .50 [16], were found for all factors.:

A. Participation effect in the value perception of a competency certification program

In what concerns the effect of participating or not in a program, taking into consideration the data gathered, it`s possible to see in *Table 3*, that the effective participation in a program has a relevant effect in the way a certification is seen, in terms of its intrinsic value (see F1: ValInt scores), its efficiency as training alternative (see F2: ValCertTrain scores), the associated effects related with career management possibilities (see F3: CertGestCarr scores), and the personal effort implied in the learning activities inherent to a program participation (see F4: EffortTrade scores).

Table 3 also reveals that there is, in particular, a significant statistical difference in the perceived intrinsic usefulness of a certification (see F1: ValInt scores), if an employee participates or not in a certification program. Despite this evidence, the scores obtained in this domain aren`t very high, when compared with the scores related with the efficiency of a certification as a possible training alternative (see F2: ValCertTrain scores), or a participation associated effects related with career management possibilities (see F3: CertGestCarr scores).

This suggests, in our opinion, that certification-oriented training programs tend to be judged in an instrumental way, more by its positive effects, benefits or rewards in terms of career management or professional within-peers recognition, than by its intrinsic value as institutional or personal development drivers. Besides the displayed analysis, a ANOVA data variance analysis was made, taking as independent variables the participation in a program and the job role of the participant, in order to perceive the nature of these variables interaction in the perceived intrinsic usefulness of a certification domain.

The effect that was obtained is statistically significant ($t = 3.79$, $p \leq .05$)

TABLE II. FACTOR LOADINGS MATRIX, AND ITEM COMMUNALITIES (H^2).

Factor	*Item*[2]	*Loading*	*h^2*
F1 [ValInt]	(CCES_3). A certified professional has a better job performance than a non-certified professional.	.724	.642
	(CCES_8) [inv]. A certification doesn`t validate a professional`s past experience or competency.	.695	.570
	(CCES_11) [inv]. A professional that isn`t certified feels less confident in his/her work execution.	.670	.459
	(CCES_19). A certification increases a professional`s level of confidence and his/her ability to be more competitive.	.636	.615
	(CCES_7). A certification is a quality guarantee of a professional`s services.	.594	.571
	(CCES_18). To be certified is to be a member of a distinctive professional group.	.556	.616
F2 [ValCertTrain]	(CCES_17). The certification is a motivating mechanism, because it helps the professional to obtain new certifications by learning new abilities.	.819	.712
	(CCES_21) [inv]. A professional certification, when compared with other training mechanisms, is a bad investment for a work organization.	.777	.737
	(CCES_9) [inv]. A professional certification isn`t necessarily a good career development driver.	.730	.644
F3 [CertGestCarr]	(CCES_10). A certified professional can obtain better salaries and benefits.	.856	.756
	(CCES_4). A certification is a driver to win several professional battles.	.703	.659
	(CCES_16). A certification can help to get a new job, in a faster and more adjusted way.	.703	.731
	(CCES_15). A certification enables a professional development congruent with personal and professional project and aspirations.	.448	.605
	(CCES_20). A certification is a proof that a professional deeply knows a particular matter, product or technology.	.421	.530
F4 [EffortTrade]	(CCES_5) [inv]. There is a large amount of psychological effort in a certification program, and the benefits don`t compensate these costs.	.881	.822
	(CCES_6) [inv]. To get a certification demands a excessive effort, when compared with possible benefits.	.820	.746
	(CCES_13) [inv]. Getting a certification mainly result from industry and market pressures, not from personal or organizational benefits.	.675	.719

[2] The scale version used in the study was originally in Portuguese.

TABLE III. PARTICIPATION EFFECT IN THE VALUE PERCEPTION OF A COMPETENCY CERTIFICATION PROGRAM.

F1	Participation	No participation	*F2*	Participation	No participation	*F3*	Participation	No participation	*F4*	Participation	No participation
M	2.96	2.69	*M*	4.14	3.91	*M*	3.85	3.82	*M*	4.12	3.56
SD	.65	.92	*SD*	.88	.81	*SD*	.67	.80	*SD*	.93	.75
t	3.79		*t*	.20		*t*	.28		*t*	.45	
p	.05		*p*	.65		*p*	.60		*p*	.50	

TABLE 4

TABLE IV. VALUE PERCEPTION OF A COMPETENCY CERTIFICATION PROGRAM: JOB ROLE AND PROGRAM PARTICIPATION INTERACTION EFFECT (MEANS).

[Participation/No participation] ***F1 (average)***	***Junior Engineer***	***Project Engineer***	***Senior Engineer***	***Engineering Manager***	***Business Developer***	***Project Manager***	***Total (n=58)***
Participation in a certification program	2.81	3.02	3.17	3.25	n.a.	2.97	**2.96**
No participation in a certification program	2.68	1.79	n.a.	1.50	3.83	3.15	**2.69**
Total	2.74	2.58	3.17	2.90	3.83	3.08	**2.83**

The analysis of the differences obtained in terms of the perceived intrinsic usefulness of a certification, considering the participants job role (see *Table 4*), reveals that higher scores are registered in management-related roles, as for engineering roles, and in particular, junior roles that don't participate in a certification program, a certification isn`t intrinsically valued as a valid professional development anchor or education driver. In these cases, expectations are somewhat low, but the effective participation in a program, apparently has a positive effect in revamping previous (low) beliefs and expectations related with the perceived intrinsic usefulness of a certification; aligned with these observation, we can state that, for this study`s sample, participation itself helps to enhance the way a certification program is intrinsically valued.

III.B. *Age and job role effect in the value perception of a competency certification program*.

Checking the effect of the variable *age* in the value perception of a competency certification program, reveals that there are differences in the perceived usefulness of a certification, and higher scores are obtained in elderly participants

groups (in particular, in the measure domains F1 and F3); in a broad sense, the older the participant is, the more likely is him/her to value the participation in a certification program.

A remark must be made, however, about this assumption: for more senior participants, probably due to the position that they already occupy in the organization (40% are Project or Senior Engineers, and 30% are Project Managers), the effort trade-off implied in a program participation isn`t unequivocally favoured (see F4 scores). Statistically significant differences were obtained in this domain ($t = 3.98$; $p < .05$), as can be seen in *Table 5*.

It`s reasonable to suppose that the higher score obtained for the intermediate age group (30-35y) can be associated to the career development stage the participants are immersed in, in the sense that a ascendant career phase can help to perceive a personal learning investment as reasonable, desirable or manageable, having in mind possible future benefits; this doesn`t occur so clearly with younger or older participants, as these benefits aren`t so clearly projected, due to the junior, low-hierarchy or more senior, top-hierarchy roles these participants have. In this sense, the variation in the degree of engagement to reason and manage the personal effort implied in a program participation and correlated learning activities, is a important variable to predict the success of these programs, and must be seen with particular caution by those who promote them, as part of a corporate skills development strategy.

TABLE 5
Age effect in the value perception of a competency certification program.

		24-29y	**30-35y**	**36-43y**
F1 [ValInt]	***M***	2.70	2.87	3.29
	SD	.75	.86	.64
	t	1.65		
	p	.20		
F2 [ValCertTrain]	***M***	3.83	4.24	4.24
	SD	.92	.81	.50
	t	1.77		
	p	.18		
F3 [CertGestCarr]	***M***	3.66	4.00	4.03
	SD	.77	.70	.54
	t	1.66		
	p	.20		
F4 [EffortTrade]	***M***	**3.61**	**4.26**	**3.62**
	SD	.91	.77	.78
	t	3.98		
	p	**.02**		

The efficiency of a program partially depends of the participants` commitment degree, and the foreseen career development opportunities associated with these participations.

Work division, organization structures and job roles career lines condition the scope and range of these opportunities, subjectively linked to promotions, functional mobility and compensation improvements. In this study, the effect of the variable job role in the value perception of a competency certification program was considered, when analyzing the differences obtained in terms of the perceived intrinsic usefulness of a certification, considering the participants job role (see *Table 4.2*); as referred, higher scores were registered in management-related roles.

This relation is corroborated by a ANOVA data variance analysis, taking as independent variables the participation in a program and the job role of the participant, in order to perceive the nature of interaction of these variables in the perceived effects of a participation in terms of career management opportunities (see *Table 6*). The effect that was obtained is statistically significant ($F = 3.69$, $p < .05$).

IV. DISCUSSION

The findings of the study fairly corroborate the initial research hypothesis related with a predicted positive effect of a concrete participation in a certification program, in the way these programs are perceived as possible skills and career development anchors. Significant differences were found in the perceived usefulness of a certification, if an employee participates or not in a certification program. The exploratory scale (CCES) presents satisfactory psychometric qualities in the used sample, but further studies are necessary with larger samples to further test the scale in other organizational contexts. In a overall sense, four specific remarks must be addressed, concerning the results that were found related with the perception of a certification program as a professional training alternative (when compared with more traditional education settings), the personal investment trade-off implied in the participation in one of these programs, and the kind of effect the effective participation has in the global judgment made about a certification program efficiency and relevance:

TABLE V. CAREER MANAGEMENT CERTIFICATION PROGRAM EFFECTS:JOB ROLE AND PROGRAM PARTICIPATION INTERACTION EFFECT (MEANS).

[Participation/No participation] ***F3 (average)***	***Junior Engineer***	***Project Engineer***	***Senior Engineer***	***Engineering Manager***	***Business Developer***	***Project Manager***	***Total (n=58)***
Participation in a certification program	3.51	3.91	4.00	4.10	n.a.	4.36	**3.85**
No participation in a certification program	3.83	3.70	n.a.	1.80	4.20	4.08	**3.82**
Total	3.67	3.84	4.00	3.64	4.20	4.18	**3.83**

a) In what concerns the effect of participating or not in a program, taking into consideration the data gathered, it`s reasonable to assume that the effective participation in a program has a relevant effect in the way a certification is seen, in terms of its intrinsic value, its efficiency as training alternative, the associated effects related with career management possibilities, and the personal effort implied in the learning activities inherent to a program participation. There is a significant statistical difference in the perceived intrinsic usefulness of a certification, if an employee participates or not in a certification program; despite this evidence, the scores obtained in this domain aren`t very high, a disposition that suggests, in our opinion, that certification-oriented training programs tend to be judged in an instrumental way;

b) The job role apparently has a modulator effect in terms of the perceived intrinsic usefulness of a certification, as higher scores were registered in management-related roles, and in particular, in engineering junior roles, a certification isn`t intrinsically valued as a valid professional development anchor or education driver. In these cases, expectations are somewhat low, but the effective participation in a program, apparently has a positive effect in revamping previous (low) beliefs and expectations related with the perceived intrinsic usefulness of a certification;

c) In a general sense, the older the participant, the more likely is he/she to value the participation in a certification program. A remark must be made, however, about this trend: for more senior participants, probably due to the position that they already occupy in the organization (40% are Project or Senior Engineers, and 30% are Project Managers), the effort trade-off implied in a program participation isn`t unequivocally favoured.

d)

e) The age-related and job role-related variations in the degree of engagement to reason and manage the personal effort implied in a program participation and correlated learning activities, is a important variable to predict the success of these programs, and must be seen with particular caution by those who promote them, as part of a corporate skills development strategy.

V. CONCLUSIONS

The relevance of this study is associated, we think, with the raising relevance of learner and individually-centered learning processes, the shift from *just-in-case* to *just-in-time* to *just-for you* education approaches [9], and the diversification of training strategies and learning *loci* that can co-exist in contemporary workspaces. Despite the growth in the use of these programs as institutional training alternatives, their success isn`t linearly guaranteed, as they depend, in a considerable scale, of the applicants` commitment to learn, their ability to control and pace learning activities, and the existence of external support and encouragement, and, for this study`s sample, the age and job role of the certification program applicants. These variables are particularly relevant if certification programs success largely depend of self-paced learning efforts, a potentially conflictive context where learning activities can be seen by applicants as a result of personal investment, and not as a result of a corporate learning policy.

Investing in formal self-paced learning efforts within the workspace imply a shift in the way training periods are conventionally planned in work organizations; creating multiple learning *loci* in contemporary workplaces, using, for instance, competency certification programs as a option, is a current managerial challenge, as it poses new involvement demands to managers and training promoters, the need for constant renewal of training materials and resources, due to high-paced knowledge erosion, and the systematic monitoring of individual, asynchronous skill adjustment efforts.

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Session: 01B Area 3: Specific Engineering Disciplines - Researches

Student Internship Placements. Improving the quality of engineering internship programs.

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Educational Research in Spain: A review through the Education Awards of CESEI - IEEE

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Directive of the Spanish Chapter of the Education Society of IEEE (Spain)

A Project-Oriented Integral Curriculum on Electronics for Telecommunication Engineers

Arredondo, Belén; Borromeo, Susana; Machado, Felipe; Malpica, Norberto; Vaquero, Joaquin

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Training Microsystems Technologies in an European eLearning Environment

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Student Internship Placements

Improving the quality of engineering internship programmes

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Abstract—**Work Internship Placements (*WIP*) is a transversal programme of enterprise internships for the engineering students of UdG which is focused on quality improvement, academic control and satisfaction of collaborating enterprises. The fundamental *WIP* infrastructure is a web-based intranet platform that provides a complete set of *WIP* tools, procedures and tasks involved in all internships stages for every participating agent: enterprises, students, coaching professors and administrative staff. Our new programme is centered on a broader, more holistic internship placement procedure than the traditional "career and academic goals" approach. The *WIP* programme has been found to be a valuable asset in addressing enterprise and student needs in the experiential project.**

Keywords: work integrated learning; engineering internship programme; quality placements; intranet web platform; internship coaching

I. INTRODUCTION

Exposing engineering students to a real working environment provides the student with a complimentary and fundamental view about engineering, being a key component in the Bologna process. This work integrated learning (*WIL*) approach could be included in the concept of "*WIL* as preparation for future employment" in the set of types of *WIL* explained by [1,5,7].

The quality of the practical placements is determined by the contents, duration, allotted credits and also by the quality of resources, the stage organization and the procedures of monitoring and evaluating the competences acquired by the students. As described in [4], the success of a practical placement model requires the design and accomplishing of a quality assurance system for the practical stages, which comprises: (1) establishing objectives and quality assurance policies, (2) establishing organizational structures and responsibilities, (3) drawing up documents and human resources assurance, (4) monitoring, analyzing and improving the quality of the educational process through practice stages.

There are no general patterns for elaborating a quality assurance system for practical placements, since their structure is influenced by the general management of the university, by the philosophy of the university regarding the place and role of the practical placements, by economic and politicalsocial factors both at national and international level. Whatever the adopted system is, in order to be efficient and functional, it must attract the participation of the whole staff and promote a new system of values in the university and in the company, specific to the quality culture, which includes continuous improvement, focus on clients, extended cooperation and partnership.

Enterprise internships have always had a great importance and interest in the bachelor engineering programs of the Polytechnic School (*EPS*) of the University of Girona (Spain). This preliminary professional training experience, carried out during the last academic year of the engineering studies, provides students with an opportunity to apply what they have learnt in a real environment and to acquire useful and efficient new work habits. Moreover, internships become a fundamental key factor in the student academic motivation, as also pointed out in [2].

Although the Polytechnic School understood internships as a key component of the academic curricula, some drawbacks were detected in the existing implementation of our internship programme. First of all, there was a lack of control of the working plan, due to a strong dissociation between the University and the enterprises. The coordinator of the engineering degree was formally responsible for the evaluation of the internships, among the many other tasks he had to carry out. Therefore, we could not effectively audit the academic contents of the internships. It should be noted that the coordinator's assessment was based only on a "*pass*/*don't pass*" strategy, and the student obtained a positive evaluation as far as he could prove that he had carried out the internship. Unfortunately, the university did not have a catalogue of companies offering internships. Therefore, the student had to look for a company, and the first contact between the university and the company was carried out by the student itself. With this situation, the offers could be too balanced towards the particular interests of either the enterprise or the student. Thus, in some cases, companies proposed working plans that were too biased towards their needs, sometimes without a valuable academic content for the student. The other undesirable situation with the existing internship model was that some students reached agreements with small companies were they had a personal/family contact, so that, in those cases, the student could not be objectively evaluated by the company. Finally, we had confirmed some cases of dissatisfaction with students regarding the academic content of their working plan, and with companies that were also disappointed because they were hiring students with the wrong profile and/or motivation.

For this reason, we started in 2005 a new transversal program of *EPS* internships that we named *Work Internship Placements* (*WIP*) which has been designed specifically to overcome the drawbacks of pre-existent programs while taking profit of their positive aspects. Thus, *WIP* is focused on internship quality improvement, increase of the academic control and, simultaneously, on promoting the interest and satisfaction of collaborating enterprises.

One of the key elements in the success of *WIP* is that it makes available to all internship participating agents (students, enterprises and university staff) a specifically designed intranet web platform which centralizes the set of tools, procedures and tasks involved in all internships stages: fluent communication among participants, partner contacts, information, registration, management, statistics and evaluation.

II. WIP METHODOLOGY

Before the deployment of *WIP*, the methodology to audit student internships was based on awarding some academic credits that were proportional to internship time. In contrast, in this new programme, students are enrolled in a specific *WIP* course –which is included in the engineering curriculum– having a selected team of coaching professors devoted to follow the advances of the student during the internship. A key point of the *WIP* programme is the adequate selection of these coaching professors, who not only monitor the internship, but also actively counsel students involved in this off-campus learning experience. For this reason, coaching professors should have experience in working with private companies, but should also know and understand the "culture" of every enterprise where a student is placed, guiding the student not only in the technical aspects of his work, but also in the typical way of behaving within the organisation. On the other hand, beyond providing support and guidance to the students, coaching professors also participate in the design of the internship activities, providing feedback to the companies and enabling synergies with existing research groups of the university that could add value to the company through technology transfer contracts. Therefore, adequate selection of coaching professors is one of the pillars for the success of the *WIP* programme.

The *WIP* programme works as follows: (1) participating entreprises and institutions propose online their *in situ* engineering placements, (2) placement proposals are revised and approved by *WIP* administration, (3) students access the web and apply for placements according the their curriculum and interests, (4) enrolled enterprises automatically receive an email with a link to examine the curriculum of the applicant every time a student selects that offer. Once the enterprise receives all the applications, the students are interviewed and, possibly with the help of coaching professors, the enterprise carries out its selection. (5) Whenever a student has been selected for a given placement, a coaching professor from *EPS* and an engineering coach from the entreprise are assigned to the student. (6) The internship starts with a meeting between the coaching professor, the enterprise coach and the student. During this meeting a working plan is defined in detail, pointing out the tasks that will be carried out by the student. (7) During the internship, those three partners are in contact at regular arranged times under the supervision of the coaching professor. (8) After the internship, the student is assessed by the coaching professor taking into account the enterprise opinion (this is carried out by contacting the enterprise coach).

III. WIP WEB PLATFORM

The *WIP* intranet Web Platform (*WIPWP*) has been designed, implemented and configured specifically by the *EPS* to satisfy the requirements of the *WIP* model (see Figure 1). From a technical viewpoint, the platform has been always hosted on a Red Hat Linux server of our faculty.

WIPWP has been developed mainly in PHP language while some user interacting functionalities had been implemented in Javascript and AJAX. *WIPWP* is supported by a MySQL independent database and performing temporary data connections with other university central databases for data interchanging.

Figure 1. *WIP* homepage. Public zone which main functions are enterprise registration and registered-user login.

Despite its faculty specificity, *WIPWP* design easily allows being adapted and configured to be used by other faculties either in our university or outside. For instance, at present, and due to the success of the *WIP* model, the Faculty of Economics of our university is finishing its own adaptation of our *WIPWP*.

Functionally and from the user point of view, *WIPWP* has been split into five "agent" zones corresponding to the actors playing a role in the *WIP* model: *public-common zone*, *enterprise zone*, *student zone*, *coaching professor zone* and *administrative staff zone*. Moreover, there is a "super-agent" zone of *administration-managing.*

The platform works always under HTTPS network protocol to provide users a secure data flow. Access to the registered "agent" zones is protected by means of user defined passwords and specific PHP authentication code, while the "super-agent" zone uses a particular HTTP authentication scheme.

A. Public-Common zone

This area is the public unregistered zone of the intranet and also the common login door to "agent" registered zones. Its main functionality is allowing the registration of new enterprises to the platform; but it contains also general information about the *WIP* performance, the list of coaching professors, the list of collaborating enterprises and the public news section.

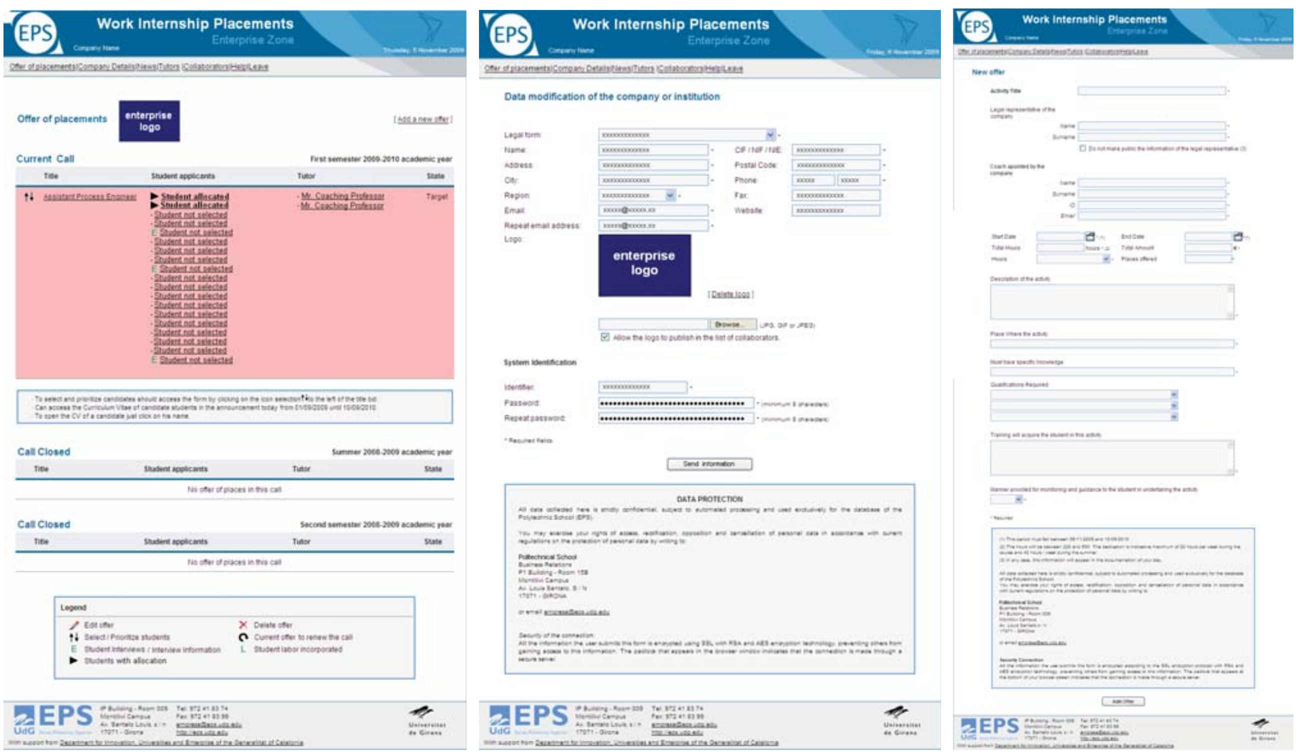
Whenever an enterprise has filled in the registration form it receives an email message to verify its email address. To verify the confidence of those registrations, the *WIP* platform administrators contact all new registered enterprises at regular intervals or whenever a new enterprise makes a placement offer.

B. Enterprise zone

As already stated above, enterprises require a compulsory registration to access this zone which is dedicated to participating enterprises (see Figures 2 and 3).

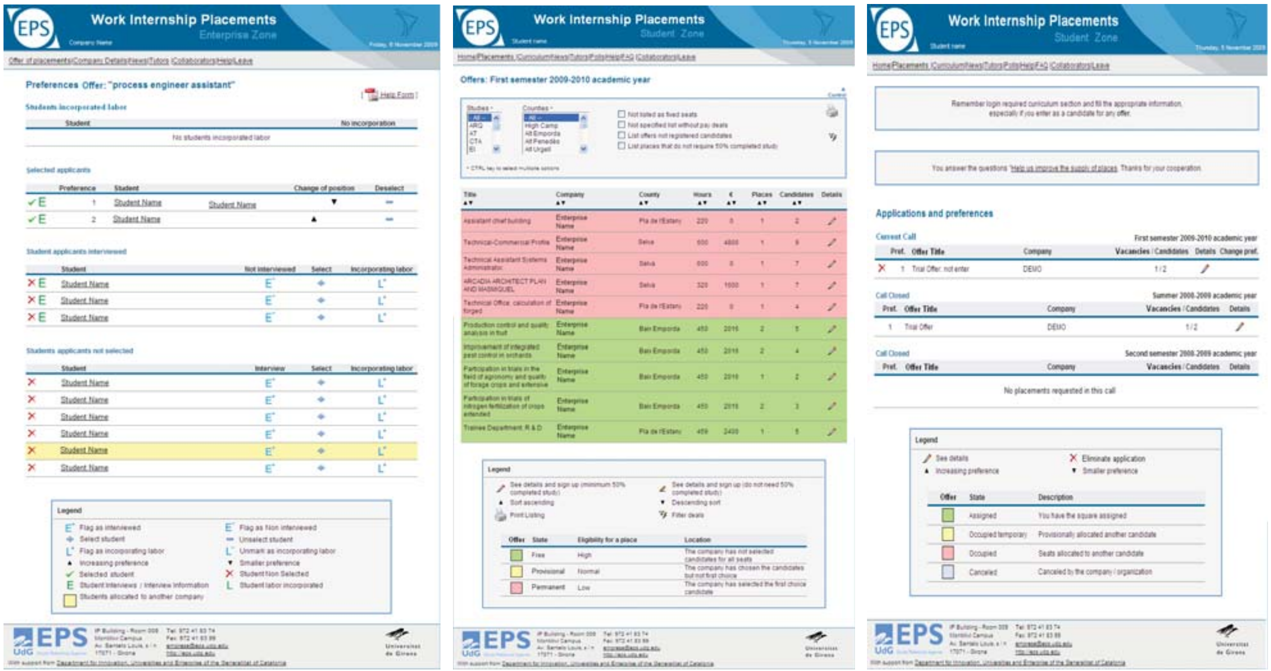
The *enterprise zone* includes the following enterprise devoted services:

- *Offers service*. It includes: adding offers, state of offers, full offer information, cancellation of offers, list of applicants for every offer, access to curriculum of the applicants, etc.



(a) (b) (c)

Figure 2. Sample web interfaces once the enterprise has registered online. (a) Information about the offers submitted by an enterprise; (b) Enterprise modification data form; (c) Placement offer form.



(a) (b) (c)

Figure 3. (a) Enterprise zone: The applicants'selection and preference setting form as seen by an enterprise. (b) Student zone: List of available placements seen by a student. (c) Student zone: A student application form

- *Selection service*. Includes: selection of applicants setting the preference order, interview information, etc.
- *Enterprise data service*. Data modification of every enterprise in the platform.
- *Coaching professors service*. The list of coaching professors (including contact information) in every *EPS* degree.
- There is also a news and documentation section, a collaborators section and a help section.

C. *Student zone*

Students, as members of the university community are already registered users of the university network, so EPS students do not need any specific registration in the *WIP* intranet and they should simply use their corresponding university intranet authentication data to access also our platform (see Figure 3 b-c).

The *student zone* includes the following student dedicated services:

- *Application service*. It includes: state of allocation, full application information, cancellation of applications, change of preferences, etc.
- *Curriculum service*. The personal data and *EPS* training data are automatically filled in, so the student needs to complete only his/her work experience and additional information.
- *Placements service*. The complete list of placement offers (details, vacancies, number of applicants, state of allocation, etc.) which can be filtered depending on student interests and the application form.
- *Coaching professors service*. The list of coaching professors (including contact information) in every *EPS* degree.
- As in the enterprise zone there is also a news and documentation section, a collaborators section, a help section, a FAQ section and a surveys section.

D. *Coaching professor zone*

As explained before in the case of students, specific registration for *WIPWP* professors is not required.

The *coaching professor zone* includes the following services (see Figure 4):

- *Coaching service*. Including: list of assigned student-enterprise pairs, partner contact information, assess form, placement documentation state, etc.
- *Enterprise service*. Complete list of enrolled enterprises with complete contact information.
- *Placements service*. Complete list of placement offers (details, vacancies, number of applicants, state of allocation, etc.) which can be filtered depending on user interests.

- C*oaching professors service*. List of coaching professors (including contact information) in every *EPS* degree.
- It also includes: a news and documentation section, a collaborators section, and a help section.

E. *Administrarive staff zone*

Administrative staff members are also users of the university network, so they do not require registration either. This zone is devoted to administrative staff services focused on providing information (list of placement offers, list of enrolled enterprises, list of coaching professors, administrative staff news, etc) and not on acting on the platform.

F. *Administration-Managing zone*

This zone is devoted to administrative and managing tasks of the *WIP* model and de managing utilities of the *WIP* web platform itself.

The *administration-managing zone* includes the following detailed and extensive management services: *enterprises, placements, applications, allocation algorithm, coaching assignments, placement documentation, coaching professors, students, emails, news, call for offers, statistics,* etc.

An interesting and useful functionality implemented in the "super-agent" zone is the possibility to emulate a login playing the role of any registered "agent" of the *WIPWP*. That login emulation is complete, in the sense that the "super-agent" could, not only monitor exactly what the emulated "agent" would see, but also act, if necessary, as the emulated "agent" itself. This emulation has several benefits: (1) instantaneous and exact monitoring of user's activities from their point of view, (2) efficiency in user problem solving, (3) executing actions on user demand, (4) testing new functionalities and (5) easiness of implementation by means of the correspondent "agent" zone services.

IV. WIP ALLOCATION ALGORITHM

Finally, *WIPWP* includes also an Automatic Allocation Algorithm (*WIP3A*) which, taking into account the declared preferences of the allocation's phase actors (placement offering enterprises and applicant students) performs the allocation.

From the *WIP3A* point of view, students can be in one of these three different allocation states:

- *Not allocated*, when the student does not have an allocation.
- *Provisionally allocated*, when the student has an allocation which he has not yet accepted, so that allocation could be replaced by other student's priority allocations.
- *Permanently allocated*, when the student has an allocation already accepted by him or an allocation which has the highest student's appliance preference.

And placements can be in one of the following four different allocation states, according to the allocation algorithm:

- *Free allocation*, the placement has no applicants or the algorithm has not set a different state to the placement yet.
- *Void allocation*, the placement does not have an allocated student after algorithm execution.
- *Provisional allocation*, whenever the placement has a *provisionally allocated* student.
- *Permanent allocation*, whenever the placement has a *permanently allocated* student.

WIP allocation proceeds as follows:

(1) Students can apply simultaneously to several placement proposals setting a preference order.

(2) Enterprises can also select several students from the corresponding applying offer list and set their preference order too.

(3) Every time *WIP3A* is executed, placements in the *void allocation* state are set to the state of *free allocation*. Then the algorithm looks for the set of placements in state of *free allocation*, which is named the *Free Placement Set* (*FPS*). One *free placement* is taken from *FPS* and named the *target placement* –i.e. the placement that the algorithm would try to allocate–. Therefore, accordingly to the enterprise preference order, the first selected *not allocated* or *provisionally allocated* applicant in a lower student preference placement, if any, would be allocated in that *target placement*; otherwise –i.e. the *target placement* has no applicants, has only applicants *permanently allocated* or *provisionally allocated* in a higher preference placement– the placement is set to the *void allocation* state. Any new allocation would be always *provisional* excepting those cases where the *target placement* has the highest student preference or the student has already accepted it; only in these above mentioned cases the allocation would be *permanent*. The target placement would be always removed from the *FPS*. One of the collateral effects of this procedure will be that some *provisional allocated placements* could be let into a *free allocation* state and added to *FPS*, because its students "had been stolen" by other placements which are more interesting for those students. The process is repeated, by taking another *free placement* from *FPS*, until *FPS* is empty (i.e. there are no *free placements* left).

(4) *WIP3A* could be executed automatically whenever any agent carries out an action or in a managing supervised scheme at regular time intervals.

Finally, it must be noticed that despite the fact that both (applicant students and offering enterprises) had pointed out its preference order and enterprises had carried out a selection of students, the final decision (placement acceptation) and the prevailing preference criteria (for instance, whenever several enterprises had selected simultaneously the same applicant student) would be, obviously, on the student side.

(a) (b)

Figure 4. (a) List of students allocated to a coaching professor. (b) List of placements (top) and list of applicants for a given placement (bottom) as seen by a coaching professor.

V. RESULTS

The Work Internship Placements programme has currently completed its fourth year of operation. Table 1 summarizes the obtained results. It should be noted that although the number of enterprises that joined the programme has been increasing at a good pace, the number of student placements has also increased, but it decreased on the last year. This decrease is explained because of the international economic crisis, which has especially affected several companies of our local industry. On the contrary, the number of students that participate in the programme has kept a constant growth, with 370 students on the last year, generating more than 850 applications. This compares to the 111 students of the first year that generated 174 applications.

One of the keystones that enables this growth is the efficient performance of our automated web service, which allows an optimal interaction between students, enterprises and academic staff. This web portal is scalable, and allows the increase of the number of internships and companies with a very limited overhead for the administrative staff.

	2005/06	2006/07	2007/08	2008/09
Enterprises in the *WIP* platform	45	100	195	230
Enrolled enterprises	35	70	130	90
Placements	76	122	213	151
Applicant students	111	171	245	370
Applications	174	288	529	869
Placements with allocation	37	55	90	78
Placements without allocation	39	67	123	73
Students evaluated as "optimum"	33	39	49	55
Students evaluated as "suitable"	4	16	24	22
Students evaluated as "unsuitable "	0	0	1	1

Table 1. Quantitative results for the first 4 years of the Work Internship Placements (*WIP*) programme.

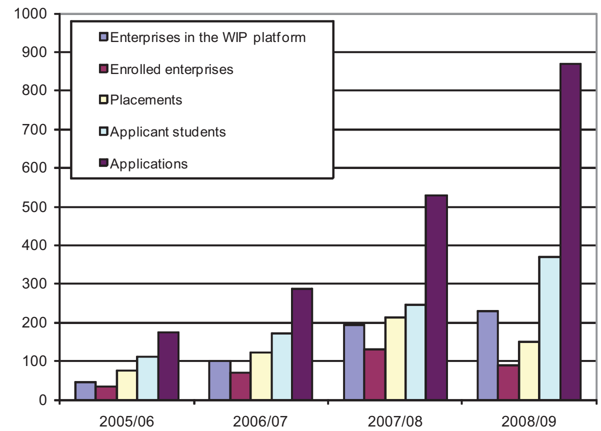
On the other hand, we observe that the performance of the students is very good. Since the students are qualified on a 3-grade system, most of them obtain the "optimum" grade, a few obtain a "suitable" and a much reduced number of students do not obtain a positive evaluation of the internship. In this grading, the coaching professors consult and take into account the opinion of the company before judging the work of the student. Finally, it should be noted that the allocation of placements works very well by automatically following the algorithm described in section IV.

It is also important to note that, currently, the programme is not pre-defined. On the contrary, it is constantly developing. Continuous interaction and dialogue between faculty and industry is the cornerstone of the internship programme. For this reason, the web service has dedicated zones to for interaction between the different participating agents (students, faculty and companies) to interact in an optimal way. Moreover, at the end of the internship, we collect the opinion and observations of the enterprise coach, the student and the coaching professor. This feedback is crucial to the success of the project and critical for adopting corrective actions in the benefit of the programme. Finally, and provided that coaching professors are a key element in the success of the project, it should be noted that efforts are also being made to obtain new faculty members with industrial experience who will eventually act as coaching professors.

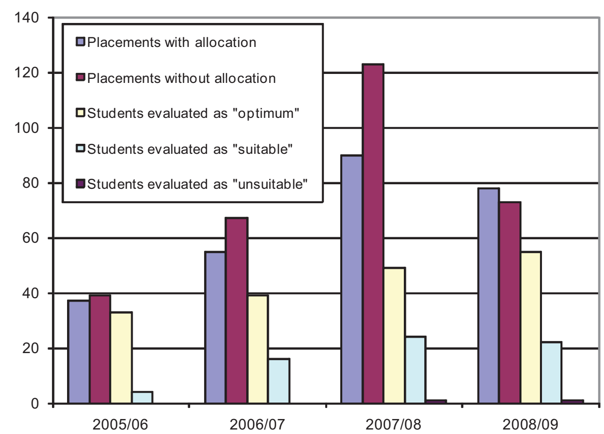
VII. CONCLUSIONS

Currently, the *WIP* course is not yet mandatory in our degree programmes, but according to the strategic guidelines of the Bologna process and as a result of its success, it will be mandatory in the near future for some of engineering degrees of EPS. This mandatory nature of the *WIP* is also supported by the regional environment business world main opinion that this course makes a very significant contribution towards providing industry with engineering graduates who are well-prepared to assume responsible and productive engineering assignments, with less need for on-the-job training and with generic skills through problem-based learning (as explained in [6]). This significant contribution agrees with many research works, for instance see the UK study presented in [3], where the author points out the positive effect of industrial placement schemes on future engineer students employability.

Moreover, it should be noted that the development of a web platform that automates and monitors the different steps of the internship process is a key tool to improve the quality both for the students and for the enterprises. This model is perfectly scalable, so that an increase of the number of internships carried out by the students of the Polytechnic School can be easily handled by the web platform.



(a)



(b)

Figure 5. (a) Evolution of the number of participating enterprises, internship offers, student demand, placements and evaluation results, for the first 4 years of the Work Internship Placements (*WIP*) programme. (b) Number of placements and evaluation obtained by the students.

Finally, we should remark that both enterprise and student feedback has been overwhelmingly positive for *WIP*, with a special emphasis in the functionality of the web application and the active participation of the coaching professors.

VIII. Future Work

The future main project related to *WIP* is the development of an automated *WIP* Survey Web Platform (*SWP*). The aim of *SWP* is obtaining useful and valuable feedback from the *WIP* participating actors (mainly enterprises and students) to improve the quality of the general *WIP* model in all its features (information, security, functionality, efficiency, etc). This survey platform, which at this moment is in a design and initial development stage, would finally be integrated in the general *WIPWP* project.

Acknowledgments

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Engineering Education Research in Spain

A review through the Education Awards of CESEI - IEEE

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Abstract—**In this paper, a review of the educational research that is being developed in Spain is realized in the areas of Electrical, Electronics, Telecommunications and Informatics through the works presented to the prizes CESEI (Spanish Chapter of the Education Society of the IEEE) in his three editions. There are two categories of candidates to the prizes, one for the Doctoral Thesis and the second for the Final Degree (or Master) Projects. An analysis of the working areas, the subjects covered as well as the conferences and journals where the results are published has been done. The main goal of this paper is to have a general vision about the work done in such areas of educational research in Spain that will be very interesting for academic staff and researchers.**

Keywords- doctoral thesis; educational research; engineering

I. Introduction

The University plays a very important role in the Society as responsible for the education of future engineers and staff members of companies and Administration. University teachers must split their work in three fields: academic, research and management. For this reason, not always they can devote enough time to the academic activity.

Nevertheless, in the last years an effort for empowering the research and innovation in education is being observed. This effort has been reflected in the increase of the number of reviews and conferences dedicated to the higher education, as well as in the number of papers published and research projects developed in this field.

In the present paper, a review has been done about the research in education carried out in Spain in the areas of Electrical, Electronics, Telecommunications and Informatics through the works presented to the CESEI prizes (Spanish Chapter of the Education Society of the IEEE) in its three editions 2007, 2008 and 2009 and for both categories, best Doctoral Thesis and best Final Degree (or Master) Projects.

In section II Spanish Chapter of the Education Society of the IEEE, organizer of these prizes will be presented. In section III, the works (doctoral thesis and final degree projects) presented to the three editions of the prizes will be analyzed. An analysis of the working areas, the subjects covered as well as the congresses and journals where the results are published will be done.

In section IV other reviews and conferences, not mentioned by the candidates to the prizes, but of great interest in the fields of research of the IEEE Education Society will be reviewed.

Finally, section V presents the conclusions of the work.

The main objective of this paper is to have a general vision about the work done in such areas of educational research in engineering areas in Spain, that we think could be very interesting for academic staff and researchers.

II. CESEI Presentation

The IEEE is a non-profit organization and is the world's leading professional association for the advancement of technology. The IEEE name is an acronym for the Institute of Electrical and Electronics Engineers, Inc. Today, the organization's scope of interest has expanded into so many related fields such Automation, Telecommunication or Informatics, but it continues to be referred to by the letters I-E-E-E (pronounced Eye-triple-E) [1].

IEEE includes many unique technical societies, active in the areas of publications, conferences and building technical communities. Between these organizations, the Education Society (EdSoc), was created with the main aim of "shall be scientific, literary, and educational in character. The Society shall strive for the advancement of the theory and practice of electrical and computer engineering and of the allied arts and sciences, and the maintenance of a high professional standing among its members and affiliates, all in consonance with the Constitution and Bylaws of the IEEE and with special attention to such aims within the field of interest of the Society" [2].

Its fields of interest are: "Educational Methods, Educational Technology, Instructional Materials, History of Science and Technology, and Educational and Professional Development Programs within Electrical Engineering, Computer Engineering, and allied disciplines" [2].

In Spain in the year 2004 was created the Spanish Chapter of the Education Society of the IEEE (from now on CESEI). The CESEI has the same interests and aims that the IEEE EdSoc has and to whom it belong, but the CESEI tries to develop its interest and aims in Spain and in Spanish language [3].

At the moment, the CESEI is constituted by a Directive Board with a Director and three committees:

- Technical Committee of Accreditation and Evaluation (CTAE in Spanish).
- Committee of Activities, Dissemination and Web (CADW in Spanish).
- Committee of Members and Relationship with Associations (CMRE in Spanish).

and four work teams as shown in Fig. 1.

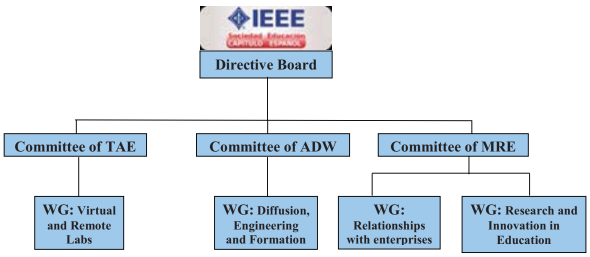

Figure 1. Structure of the Spanish Chapter of the Education Society of the IEEE (CESEI).

Since his creation in 2004, the CESEI has tried to be a meeting point for the responsible from the University as from the Enterprise that work for the improvement of the teaching of engineering and computing .

For that reason, between others, promotes the next activities:

- Edition of the International Review, edited in Spanish and Portuguese, IEEE-RITA (Latin-American Learning Technologies Journal) [4].
- Edition of the book: TICAI (TICs applied to learning of Engineering) [5]
- Collaboration with different congresses and workshops related with Higher Education.
- The prize to the best doctoral thesis and to the best final year project "Premios CESEI".

In the next section, the results of the last activity will be analysed.

III. The CESEI Awards

Among the activities promoted by the CESEI in the year 2006 one of the most relevant was the prize for the best doctoral thesis and for the best final degree (or master) project, being the thematic related totally or partially with the research or technological applications with the education in the frame of the disciplines of the IEEE, areas of Electrical Engineering, Electronics, Telecommunication Engineering and Informatics.

Since then, three editions of the prizes have taken place, covering the works developed between October 2004 and September 2008. The fourth edition, covering from October 2008 to September 2009, is running now. In those prizes, a total of 85 final year projects (PFC) and 21 doctoral theses have been presented, as it can be seen in the table I.

The number of works received as candidates to the prizes allow to do an analysis about the educational research that is being developed in Spain in the fields of interest of the IEEE and, in consequence, in the CESEI.

TABLE I. Summary of numbers of PFC and Thesis in the period

Year	PFC	THESES
04/06	19	5
06/07	39	8
07/08	27	8

First of all, the analysis of the working areas and the subjects covered by the works will be considered. In table II, data corresponding to the final degree projects are shown. With respect to the fields of interest, clearly three lines of work are more relevant: Tools and Strategies applied to the education, Special education and Virtual instrumentation-Remote laboratories.

Moreover the two first fields are very related with the area of Higher Education, it is important to remark the interest generated in Spain for the elaboration of educational materials to facilitate the education of disabled people (12% of the projects).

As well, the 35% of the total of the works is dedicated to education (tools, strategies, laboratories or virtual instrumentation).

TABLE II. Subjects – Final year project (PFC)

Topic	Percentage
Tools / Strategies applied to Education	24,7
Special Education	11,8
Remote laboratories – Virtual instrumentation	10,6
Several	10,6
Signal theory	7,1
Networks	5,9
Image Processing	4,7
Not related with the areas of CESEI	4,7
Computer architecture	3,5
Informatics Security	2,4
Web Semantics	2,4
Domotics	2,4
Electronics – Electronic Systems	2,4
Programmable Logic Devices	2,4
Electricity/ EMC	2,4
Antennas	2,4

In Figure 2, the fields of work of the doctoral thesis are shown. 76% of the thesis corresponds to Computer Engineering and Telematics-Telecommunications (38% for each one).

Up to now doctoral theses from the field of Electronics have not been received and only a 5% belong to the Electrical Engineering field. This can be due to two reasons:

- In these fields there is less research in educational topics related with engineering.
- Researchers of these fields are not interested in the prize.

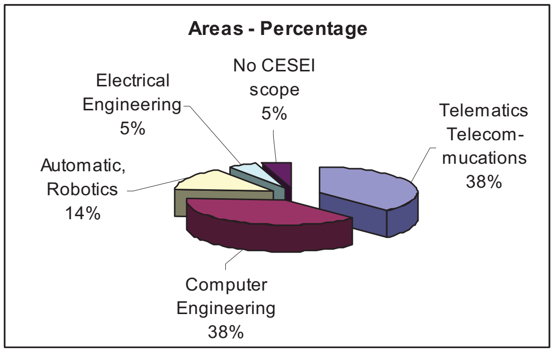

Figure 2. Percentage of doctoral theses in function of the field.

With respect to the doctoral theses, it could be of interest to know the journals in which the results of the research have been published. This information could help to the dissemination of the results of the research in education to other researchers.

Table III shows these journals. An analysis of this table allows concluding that the dissemination of the research results has been realized through specialized education journals, but as well, through other kind of technological journals non related directly with education. The reasons could be different:

- Several technical publications allow works related with the education.
- Researchers have separated the technical aspects of their doctoral theses from the educational aspects, sending each part of the work to a kind of review.

The number of journals where it is possible to publish a work in educational research for our areas of interest is very large (44 different journals identified).

TABLE III. JOURNALS

1	ACM Journal on Educational Resources in Computing
2	ACM SIGPLAN Notices
3	Advanced Technology for Learning
4	Artificial Intelligence Review
5	Automatica (Automatics)
6	Computer Applications in Engineering Education
7	Computers and Chemical Engineering
8	Computers and Education
9	Computers in Human Behavior
10	Computer Standards & Interfaces
11	Educational Technology & Society
12	Electronic Notes in Theoretical Computer Science
13	Expert Systems with Applications
14	Future Generation Computer Systems
15	IE Communications
16	IEEE Computer
17	IEEE- RITA (Revista Iberoamericana de Tecnologías del Aprendizaje)
18	IEEE Transactions on Education
19	IEEE Transactions on Circuits and Systems for Video Technology
20	Informatics in Education International Journal
21	International Journal of Electrical Engineering Education
22	International Journal of Engineering Education
23	International Journal of Modeling, Identification and Control (IJMIC)
24	International Journal on Advanced Technology for Learning
25	Journal of Interactive Media in Education
26	Journal of Process Control
27	Journal of Universal Computer Science
28	Lecture Notes in Artificial Intelligence
29	Lecture Notes in Computer Science
30	Lecture Notes in Informatics
31	Mathematical and Computer Modeling of Dynamical Systems
32	Novática. Revista de la Asociación de Técnicos de Informática
33	Pattern Recognition
34	Revista Iberoamericana de Educación a Distancia (RIED)
35	Revista Iberoamericana de Informática Educativa
36	Revista Iberoamericana de Inteligencia Artificial
37	Revista Latinoamericana de Investigación en Matemática Educativa (Relime)
38	Revista Latinoamericana de Tecnología Educativa
39	Science of Computer Programming
40	Software - Practice and Experience
41	The European Journal for the Informatics Professional
42	Upgrade. The European Journal for the Informatics Professional
43	Virtueller Campus
44	WSEAS Transactions on Systems

With respect to conferences the information is relevant. In Table IV the conferences related directly with the education have been selected. Nevertheless, the authors of the doctoral thesis have published their work in more than 50 conferences not related directly with education.

It is important to note that, in Tables III and IV, it is possible to find English language publications as well as Spanish publications, so it is very easy for authors to publish the results of their work.

TABLE IV. EDUCATIONAL - CONGRESSES

1	Advances in Web-Based Learning (ICWL)
2	Conference of the International Group for the Psychology of Mathematics Education
3	Conference on Educational Uses of Information and Communication Technologies – IFIP Conference
4	Conference on Innovation and Technology in Computer Science Education (ITiCSE)
5	Conference on New Technologies in Science Education
6	Conference on Technology Enhanced Learning (ECTEL)
7	Congreso de la Red Estatal de Docencia Universitaria (RED-U)
8	Congreso Iberoamericano de Informática Educativa
9	Congreso Internacional de Ensino da Matematica
10	Congreso Internacional EDUTEC
11	Congreso Internacional Virtual de Educación (CIVE)
12	Congreso Multimedia Educativo
13	Congreso Universitario de Innovación Educativa en las Enseñanzas Técnicas (CUIEET)
14	Computers and Advanced Technology in Education
15	International Computer Supported Collaborative Learning Conference (CSCL)
16	Frontiers in Education Conference (FIE)
17	EAEEIE Conference on Innovations in Education for Electrical and Information Engineering
18	E-COMM-LINE
19	EDEN Conference
20	Educational Innovations in Electrical and Information Engineering
21	EduTech
22	E-Learn
23	Encuentro SCM-FEEMCAT sobre la enseñanza de las matemáticas
24	European Conference on Technology Enhanced Learning
25	IASTED Int. Conf. on computers and Advanced Technology in Education
26	IASTED International Conference on Web-Based Education (WBE)
27	IEEE International Conference on Advanced Learning Technologies (ICALT)
28	IFIP World Conference on Computers in Education
29	Informing Science & Education Conference
30	Interactive Aided Learning Experiences and Visions (ICL2001)
31	International Conference on Artificial Intelligence in Education (AIED)
32	International Conference on Engineering and Computer Education (ICECE)
33	International Conference on e-Learning and Distance Learning
34	International Conference on Information Technology Based Higher Education and Training (ITHET)
35	International Conference on Multimedia and Information & Communication Technologies in Education (m-ICTE)
36	International Conference on New Educational Environments
37	International Conference on Virtual University
38	International Seminar on Innovative Teaching and Learning in Engineering Education
39	International Symposium on Computers in Education (ISCE)
40	Jornada sobre Aprendizaje Cooperativo (JAC)
41	Jornadas sobre el Aprendizaje y Enseñanzas de las Matemáticas
42	Modeling in Science Education and Learning.
43	Online Educa
44	RIBIE (Red Iberoamericana de Informática Educativa)
45	Seminario de Investigación en Tecnologías de la Información Aplicadas a la Educación (SITIAE)
46	Simposio Internacional de Informática Educativa (SIIE)
47	Simposio Nacional de Tecnologías de la Información y las Comunicaciones en la Educación (SINTICE)
48	Simposio Pluridisciplinar sobre Objetos y Diseños de Aprendizaje Apoyados en la Tecnología
49	TELearn 2008
50	TENCompetence Open Workshop on Current research on IMS Learning Design and Lifelong Competence Development Infrastructures
51	UICEE Annual Conference on Engineering Education
52	Virtual Educa
53	World Conference on Educational Multimedia, Hypermedia and Telecommunications

IV. OTHER PUBLICATIONS

Moreover the high quantity of conferences and reviews mentioned in previous paragraphs, there are other important publications where it is possible to publish the results of the research work in education and that can be of interest to the researchers.

Some of them are listed below [6]:

A. *Journals*

- International Journal of Technology and Design Education.
- Journal of Engineering Education.
- Journal of Educational Technology & Society.
- Revista Electrónica de Investigación Educativa (REDIE).

B. *Conferences*

- CAFVIR: Congreso Iberoamericano sobre Calidad de la Formación Virtual.
- CSCL: Computer Supported Collaborative Learning.
- CUIEET: Congreso Universitario de Innovación Educativa en las Enseñanzas Técnicas.
- ICCE: International Conference on Computers in Education.
- ICEER: International Conference on Engineering Education & Research.
- ICLS: International Conference of the Learning Sciences.
- IEEE - EDUCON: IEEE Engineering Education Conference.

- TAEE: Tecnologías Aplicadas a la Enseñanza de la Electrónica.

V. Conclusions

During the last years it has been possible to observe an increase of the interest for the research in education in particular in engineering areas. In this sense, since 2004 the Spanish Chapter of the Education Society of the IEEE (CESEI) is working for improving both teaching and learning of engineering and computing.

Among the activities promoted by the CESEI in the year 2006, the prize to the best doctoral thesis and to the best Final Degree (or Master) Project, being the thematic related totally or partially with the promotion of the research or technological applications in the education in the frame of the areas of Electrical Engineering, Electronics, Telecommunication Engineering and Informatics.

The number of works received as candidates to the prizes (106) allows performing an analysis about the educational research that is being developed in Spain in the fields of interest of the IEEE.

In the Final Degree (or Master) Project, in spite of the great variety of themes, there are three main areas of work: Tools and Strategies applied to the education, Special education and Virtual instrumentation-Remote laboratories. The second one represents the 12% of the total final year projects, that reveal the importance that this field is gaining in Spain in the last years.

The 76% of the doctoral theses received deal with Computer Engineering and Telematics-Telecommunications (38% respectively for each one). No doctoral theses have been received from the area of Electronics Engineering and only 5% of Electrical Engineering.

The results of the doctoral theses have been published in a large number of technical reviews and conferences (53 about education) so in English language as in Spanish or Portuguese.

The data allows encouraging the academic staff to work in this research field because they have a lot of possibilities to show and discuss the results of their work at the same time they increase the results for both areas of work the education and the research.

The main objective of this paper has been to show a general vision about the work done in such areas of educational research in Spain, that we think that could be very interesting for academic staff and researchers.

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A Project-Oriented Integral Curriculum on Electronics for Telecommunication Engineers

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Abstract— **This paper describes the Electronics curriculum in the Telecommunication Engineer degree at Rey Juan Carlos University (URJC) in Spain. Telecommunication Engineering started in the 2003-2004 academic year. In these years, all the electronic courses have been set up with a main practical orientation and with Project Based Learning (PBL) activities, both compulsory and voluntary. Once these courses have been successfully implemented we have reoriented some of the practical activities to be more interlaced. In this sense, projects involving students of different courses have been developed, as well as projects involving students from different years. All these activities fit in the principles promulgated by the Declaration of Bologna, which results in the actual updating of the university degree structure in Spain.**

Keywords: integral curriculum, Electronics, project-oriented, Bologna process

I. INTRODUCTION

This paper describes the Electronics curriculum of the Telecommunication Engineer degree at Universidad Rey Juan Carlos (Spain). Telecommunication Engineering was established in the 2003-2004 academic year. In these years, all the electronic courses have been set up with a main practical orientation and with Project Based Learning (PBL) activities, both compulsory and voluntary. In addition, the electronic curriculum has been consistently defined considering the contents and the relationships among the courses. These courses have been successfully implemented [1], [2].

Project-based learning is an instructional method that challenges students to think critically and enhance their ability to analyze and solve real world problems, develop skill in gathering and evaluating the information needed for solving problems, gain experience working cooperatively in teams. Successful implementation of Project Based Learning (PBL) strategies has been well documented [3-5].

Moreover, the regulatory modifications promulgated by the Bologna Process results in the implementation of new university degrees structures in Spain [6] and the adoption of the European Credit Transfer and Accumulation System (ECTS) [7]. This process implies a shift from traditional teacher-centered to a learner-centered approach, thus new teaching methodologies have to be introduced that focus on a more active participation of students in their learning process.

In this context, we have reoriented some of the practical activities to be more interlaced. Projects within more than one course and activities among students of different courses have been developed. Moreover, projects to be executed in more than one academic year have been planned. The implemented curriculum structure and the new activities proposed, allow a seamless transition to the Bologna Process.

This paper is structured as follows; section 2 presents the electronics curriculum context and the relationship among different courses and a description of the details, methodology, contents, evaluation data and organization of every course. Section 3 describes the recently introduced PBL activities among different courses. Finally, the results are summarized and discussed, and the conclusions are presented.

II. ELECTRONICS CURRICULUM IN TELECOMMUNICATION

Prior to the implementation of the Bologna Process, the Telecommunication Engineering degree was structured in five years, each one having two semesters. Each semester has an average of 36 credits. Each credit is equivalent to 10 hours of lessons including lectures and labs. A final degree project has to be presented (9 credits). The aim of this project is to develop a supervised complete engineering project, as a first approach to the student's future professional activity. It is equivalent to a MSc. Thesis.

Figure 1 shows the courses related to Electronics in the Telecommunication degree. All these courses are compulsory and, except for those shaded, are taught by the department of Electronics. Therefore, we have been able to elaborate a complete and comprehensive Electronics curriculum with no overlapping contents.

As can be seen, the courses cover both digital and analogue electronics. Besides, there are some other courses very closely related to the electronics curriculum. Computer Fundamentals, taught in the second year (fig. 1), are a required background for following courses. There is also a course on Communication Terminals, given in the fifth year, focused on the terminals basic specifications and internal block architecture.

Even though it is not shown in fig. 1, it is worth noticing that second year students also attend Photonics, covering the basis aspects of optoelectronic devices (LEDs, Photodiodes, Lasers…). This subject together with AE, will serve as background for Optical Communications I and II, which will be taught in the fourth and fifth years respectively.

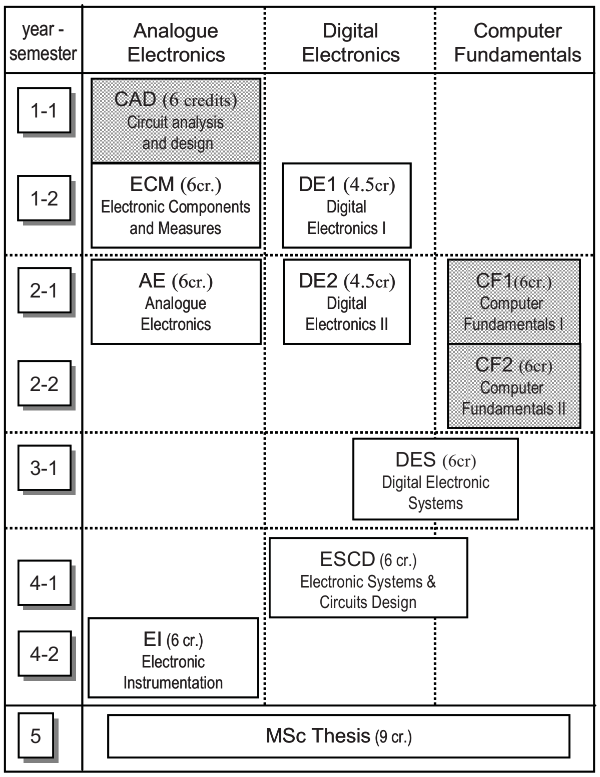

Figure 1: Electronic and related courses in the degree

On their fifth year, students who want to broaden their knowledge of electronics can work on their MSc. Thesis in our department.

Finally, it is also worth mentioning the approximate number of students attending electronic courses in each year. First year students attending ECM and EDI are around 150 divided in two groups, with one professor per group, and the support of another professor for laboratories. Second year students coursing AE and EDII are around 80 divided in two groups, with two professors both for theory and laboratory. Third year students coursing DES are approximately 60, with one professor for theory and two for the laboratory. Fourth year students coursing ESCD and EI are approximately 30, with one professor for theory and laboratory.

Following, a brief description of each course will be given.

A. Electronic Components and Measurements (ECM)

The Electronic Components and Measurements (ECM) course is a 6 credit second semester, first year compulsory course. ECM comprises theory (3 credits), practical exercises in class (1.5 credits) and practical work in the laboratory (1.5 credits). The essential background on circuit analysis is provided by the first semester, first year course on Circuit Analysis & Design (CAD) as can be seen in fig. 1. Therefore, students are familiar with linear circuit analysis with basic passive components, resistors, inductors and capacitors. On the other hand, this course provides the necessary knowledge on basic electronic components needed for the second year Analogue Electronics (AE) course.

According to the number of students and available laboratories, the students are divided in two groups for theoretical lectures and practical exercises classes and in three groups for laboratory work.

The aim of the ECM course is the learning of electronic fundamentals, including semiconductor principles and basic analogue circuits with individual components, and basic laboratory procedures, such us instrumentation use, measurements techniques and safety procedures. First, the Operational Amplifier is introduced, as a “black box”, in both linear and non-linear circuits. This allows the student to design fully functional basic circuits from the very beginning. Then, the principles of the rectifier and Zener diode and associated basic circuits are deeply studied, followed by other diode types (Schottky, LED, photodiode, tunnel) explanation. Finally, Bipolar and FET transistors are studied both following the same scheme; principles, models, DC analysis, applications and ideal-actual component comparison. The AC analysis is also explained as an introduction to AE course.

During theoretical lectures, multiple practical examples are used in the explanation. Practical exercises classes are reinforced with circuit simulations. Students have circuit simulation software available in free-access computer rooms. Laboratory work comprises a theoretical circuit to be studied analysis, circuit simulation, practical circuit implementation and critic practical-theoretical results comparison. This work is divided in five different guided sessions:

- Linear circuit analysis, where instrumentation use and measurement techniques are applied to simple linear circuit, so the student acquires the necessary skills
- Circuit simulation software, that will be used in the following sessions
- Operational Amplifier linear circuits implementation
- Basic rectifier diode circuits
- Bipolar transistor basic circuits.

The final mark is given by the exam mark weighted by 0.7 plus the laboratory mark weighted by 0.3. A minimum of 4 over 10 points are needed in the exam mark to pass the course. Laboratory work is evaluated in situ and, in addition, students must prepare a final report of each laboratory session.

B. Digital Electronics I (DE1)

The Digital Electronics I (DEI) course is a 4.5 credit second semester, first year compulsory course. DEI comprises theory (3 credits), practical exercises in class (0.5 credits) and practical work in the laboratory (1.0 credits). This is the first course on digital electronics in the degree, and provides the necessary knowledge on basic digital electronics needed for the second year Digital Electronics II (DEII) course, and for the higher level courses on electronic systems.

The aim of the course is to introduce the basic concepts in digital electronics, from numbering systems to simple sequential circuits. The following subjects are covered:

- Introduction to digital vs. analogue electronics. Review of sampling and quantification, advantages of electronics, brief history.
- Numbering systems and codes: Basic binary numbering systems (1's complement, 2's complement) and coding is presented. Binary arithmetics.
- Boolean algebra, logical functions and function simplification.
- Logical gates: Definition of the different logical gates, equivalences among them, and a short chapter on fabrication technologies and logical families.

The rest of the course deals is devoted to block design::

- Standard combinational blocks: review of the different blocks, practical designs using them. The chapter ends with the Arithmetic-Logic Unit, which serves as a review of the different block functions.
- Sequential circuits. Only biestables, registers and counters are studied, leaving more complicated designs for Digital Electronics II (DE2).

Students carry out two types of lab work. In the first session, they measure the features of several logical circuits and learn how to build simple circuits with discrete components. The second part of the course consists in designing and simulating circuits using schematics. We use the ISE-WebPack environment (Xilinx, San Jose, CA). Students are required to take three compulsory lab sessions and can also undertake several voluntary designs.

The final grade is given by the exam mark on top of which the laboratory mark is added (ranging from 0 to 1). A minimum of 4 over 10 points are needed in the exam mark to pass the course. Laboratory work is evaluated in situ and, in addition, students should send the project (schematics file) to be evaluated by the professor.

C. Digital Electronics II (DEII)

The digital electronic II (DE2) course is a 4.5 credit second year compulsory course. DE2 comprises theory (1.5 credits) and practical work in the laboratory (3 credits). Students taking this course have already a digital electronic background provided by the second semester, first year course on digital electronic I (DE1) where the have been taught the theoretical fundamentals of digital electronic design at logic level and logic-block level.

The aim of DE2 course is twofold: analyze and design sequential circuits and provide the necessary knowledge on the VHDL hardware description language. During the course, students will deep in digital design methodology. They will learn the methodology to design moderately complex digital circuits using finite state machines, computer-aided design (CAD) tools, VHDL and programmable logic devices (FPGAs). This course provides the necessary knowledge on digital design needed for the fourth year ESCD course.

The course takes place in a lab equipped for digital electronics. Designs are implemented in the Pegasus FPGA Board (Digilent, Pullman, WA) using Xilinx ISE. In this course students learn the design methodology and the hardware description languages (VHDL) in a practical way. This practical work consists of ten lab sessions where several FPGAs based systems of incremental complexity are implemented. The sessions are structured as follows:

- Introduction to development environment: Pegasus FPGA board and Xilinx ISE.
- VHDL design: concurrent sentences and process. The purpose of this session is to design standard combinational blocks: multiplexers, code converter and 7- segment decoder.
- VHDL sequential circuits: flip-flops, counters and shift register.
- VHDL for simulation: design of testbenches.
- Design of system based on finite states machines: door lock, vending machine and controlling the speed of a DC motor circuit using PWM.

The final grade is given by the exam mark on top of which the laboratory mark is added (ranging from 0 to 1). A minimum of 4 over 10 points are needed in the exam mark to pass the course. Laboratory work is evaluated in situ and, in addition, students should send the project (VHDL code) to be evaluated by professor.

D. Analogue Electronics (AE)

The analogue electronic (AE) course is a 6 credit second year compulsory course. AE comprises theory (4.5 credits) and practical work in the laboratory (1.5 credits). Students taking this course have already an analogue electronic background provided by two different first year courses (Circuit Analysis & Design (CAD), and Electronic Components and Measurements (ECM)) as can be seen in fig. 1. Therefore, students coursing AE possess significant knowledge of circuit analysis techniques, and deep understanding of simple analogue circuits with individual components.

The main aim of the AE course is to analyze and design fairly complicated amplifier circuits based on single components. First, standard parameters such as gain, input and output impedance of typical amplifier configurations using Bipolar and FET transistors are studied. This is followed by a deep analysis of frequency response and typical feedback networks. Finally, the course ends up with a quick review of power stage amplifiers.

During theoretical lectures, multiple practical examples are introduced in the explanation. Besides, in order to pass the course, students are obliged to attend practical work in the laboratory. This practical work consists of six guided sessions in the laboratory. Three different experimental setups are proposed, corresponding to the design and analysis of different amplifiers:

- Design and analysis of a voltage amplifier
- Design and analysis of a current amplifier

- Analysis of a multiple-stage amplifier (power amplifier).

Students are evaluated in situ in the laboratory and, in addition, they will hand in a final report of the laboratory work. Those with a good laboratory work can raise the exam mark up to one point (provided they obtained a minimum of 4 over 10 in the exam). Thus, the final grade is given by the exam mark on top of which the laboratory mark is added (ranging from 0 to 1).

E. Digital Electronic Systems (DES)

The Digital Electronic Systems (DES) course is a 6 credit third year compulsory course. DES comprises theory (3.0 credits) and practical work in the laboratory (3.0 credits). Students taking this course have already a background on digital electronics provided by two first and second year courses (Digital Electronics I and II), and knowledge of microprocessor architecture and assembler language, provided by Computer Fundamentals I and II, as can be seen in fig. 1.

The aim of the course is to learn how to design simple embedded systems based on microcontrollers. Students learn microcontroller architecture in detail as well as A/D conversion in class lessons. Half of the course is devoted to lab work, where several microcontroller based systems of incremental complexity are implemented. A PIC16F676 from Microchip (Chandler, AZ) and the rfPICKit1 have been selected as lab tools.

A first lab assignment is a simple traffic light controller. The second assignment involves Analogue to Digital conversion from a LM35 temperature sensor. The aim of the third assignment is the connection of a LCD display to the PIC controller. Both ideas are integrated in the next assignment, in which a converted temperature is displayed in the screen. The last assignment consists in controlling a fan using a step motor through PWM according to the temperature of the room.

All lab work is carried out in assembler language, which students have already used in a previous course on microprocessor architecture. Although higher level languages are now commonly used for microcontroller programming, we think working directly with assembler is the best way to learn the architecture in detail.

Students are evaluated in situ in the laboratory and, in addition, they will hand in a final report of the laboratory work. Those with a good laboratory work can raise the exam mark up to one point. Thus, the final grade is given by the exam mark on top of which the laboratory mark is added (ranging from 0 to 1).

F. Electronic Systems and Circuis Design (ESCD)

The ESCD course [1] is a fourth year 6 credit compulsory course. The main objective of the course is to make students face the challenge of designing real digital electronic systems, showing the different design alternatives and their tradeoffs. As it can be observed in fig. 1, students taking this course have demonstrated their fundamental theoretical knowledge in digital design, computer architecture and analogue electronics. Thus, in this course we want students to learn the design methodology in a practical way, assimilating the acquired knowledge in those courses and above all, that they face the real problems of digital electronic design and that they are able to solve them.

The contents of the course cover issues related to design methodology of complex circuits (modular design, reuse, testability, optimization), circuit interfacing and specific circuits, such as arithmetic circuits.

The course follows a PBL methodology. Rather than following a course based on the contents, we have decided to propose projects that introduce the students to those contents. Hence, during circuit design students face new challenges, and find the need to solve these problems. This raises their interest in the different solution methods.

The course has been structured in three kinds of classes: Seminars, guided laboratories and final project

Seminars are theoretical classes given throughout the semester. These seminars introduce the initial subjects and present each guided laboratory and the final project. These seminars summarize the problems that the students will face and the different approaches to tackle them. References are also included for further research.

The **guided laboratories** are the main learning method of the course. Students are faced with design projects of incremental complexity. The implementation of these projects leads the students to acquire the necessary experience to deal with the final project. Examples of these projects are the design of an UART, VGA controller, or a tennis videogame.

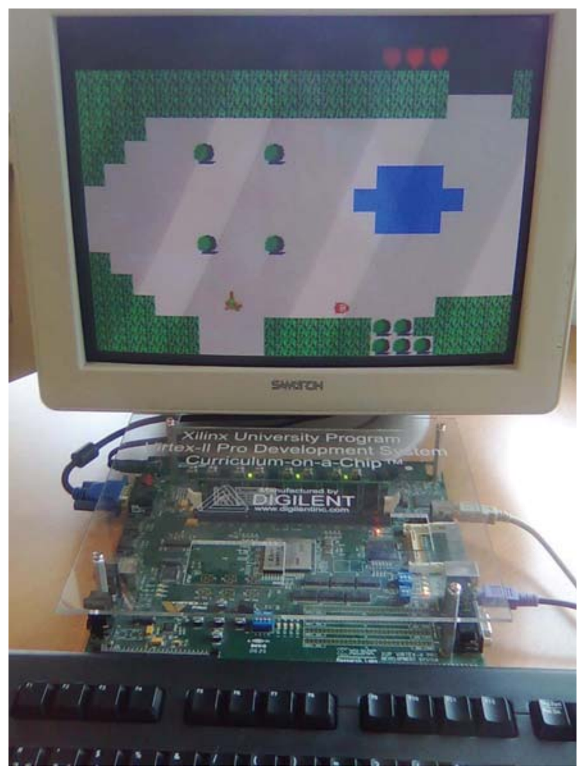

Figure 2: Snapshot of a videogame final DCSE project

Figure 3: Snapshot of a digital video final project

There is a continuous and formative assessment throughout the semester, in which alumni are provided with information on the adequacy and evolution of their work. Students are evaluated by their final project (70%) and theoretical exams (30%).

G. *Electronic Instrucmentation (EI)*

The EI course is a fourth year 6 credit compulsory course. The fundamental concepts and methodologies of electronic instrumentation are covered in this course. The course has been structured in theoretical lectures, laboratories (1.5 credits), and two design projects.

The contents of the course cover issues that have not yet been studied, i.e., sensors, the design of signal conditioning circuits, an elementary introduction to signal transmission, several lectures on noise and interference and LabView (NI, Austin, TX) virtual instrumentation and data acquisition software.

The students carry out two types of lab work. In the first sessions, they use discrete components and two different experimental setups are proposed:

- Analysis and measurement of real operational amplifier parameters
- Design of the RTD sensor conditioning circuit.

During the final lab sessions, students learn about NI LabView environment and the basics of data acquisition. Finally, they will develop an analogue input tool based on the RTD conditioning circuit designed in former sessions and on the NI USB-6009 Data Acquisition board.

On the other hand, students must hand in two design projects. The aim of these projects is to design a basic measurement system. Students should be able to understand the main specifications of a measuring system, select a specific sensor for an application, design conditioning circuits, connect sensors and actuators and integrate the measuring system to microcontroller-based systems. The design of a basic weather station capable of measuring the main meteorological variables: temperature, pressure, humidity, and wind speed is an example of a final project.

The final grade is given by the exam mark weighted by 0.8 plus the design project weighted by 0.2. A minimum of 4 over 10 points are needed in the exam mark to pass the course.

III. Project Based Learning Among different Courses

We are currently carrying out voluntary lab works involving knowledge of different courses. In these labs, students of different courses jointly develop an electronic design. These labs follow a PBL methodology, in which the circuit specifications are given at the beginning and students have to find their own solution and build the circuit design. The projects have minimum goals, but proposals to enhance the project goals are provided, in case the students wish to continue developing it.

These labs are carried out during the first half of the course; therefore, the students perform them as they start with the contents given in their respective courses. This approach has the following “benefits” for the student:

- Students have the need to acquire the knowledge of the course prior to the exam and the compulsory labs.
- Students have investigated different solutions and have implemented the solution they think is more adequate.
- When the course contents are given during the compulsory classes and labs, students can compare their solution with other solutions.
- Students reinforce their knowledge when the contents are given during the classes and compulsory labs.

We have developed two kinds of projects:

- Horizontal projects
- Vertical projects

The horizontal projects involve students of the same year. For this kind of projects, the participants are students of Digital Electronics II (DE2) and Analogue Electronics (AE), both belonging to the first semester of the second year. These projects can be considered as horizontal in the sense that all students have the same level.

The vertical projects involve students of different years; therefore, the participants have different knowledge in electronics. These projects are considered as vertical since students of upper courses guide the other students. As a result, some students have to coordinate the project and guide the others. As a consequence, the competences learned are wider than those learned in a same-year project.

Following, two of these projects will be described.

A. *Electronic Piano Project*

The electronic piano is a horizontal project carried out by students of Digital Electronics II (DE2) and Analogue Electronics (AE), both courses given during the second year.

The basic project consists in a digital square wave generator whose output is amplified to be heard through a small speaker. Fig. 4 shows the scheme of the basic electronic piano project. The digital part of the project is developed in a FPGA using VHDL and the output is amplified using analogue components.

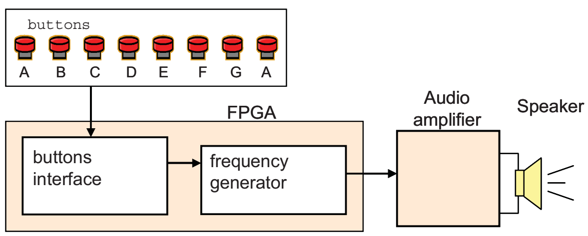

Figure 4: Basic electronic piano project

A minimum of eight frequencies have to be generated using one of the octaves. Table 1 shows some of the frequencies that could be used to generate the notes of an octave.

TABLE 1: FREQUENCIES OF THREE OCTAVES

Note / Hz	A	B	C	D	E	F	G	A
	220.00	246.94	261.63	293.67	329.63	349.23	392.00	440.00
	440.00	493.88	523.25	587.33	659.26	698.46	783.99	880.00
	880.00	987.77	1046.5	1174.7	1318.5	1396.9	1568.0	1760.0

The audio amplifier has to be built considering the working frequencies. Fig. 5 shows the general scheme on an amplifier.

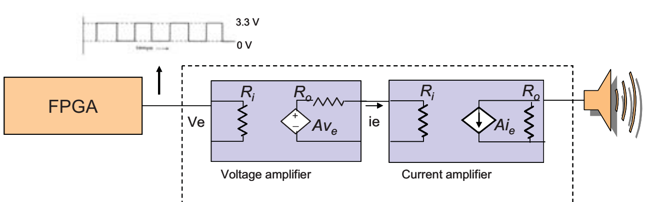

Figure 5: General scheme of an amplifier

Several considerations must be taken into account in order to design the audio amplifier. The output of the FPGA is a square signal with amplitude varying from 0 to 3.3 V; therefore, the output level is high enough to consider that the voltage amplifier stage of fig. 3 is not that critical. Loudspeakers introduce an 8 ohms load resistance and consume a power of 0.5 watts.

Finally, the amplifier bandwidth must be designed considering the frequency notes. In order to amplify the three octaves of table 1, low frequency should be one decade below 220 Hz. In this sense, external coupling capacitors should be carefully chosen. In the working frequency range, high frequencies pose no problems, since internal transistor capacitors introduce a cut off frequency well above 1760 Hz.

1) *Electronic Piano Enhancements*

The electronic piano can be enhanced in many ways. Some proposals are given to the students; nevertheless, they are free to propose any idea the like. The proposed enhancements are:

- Display the frequency or the note name through four seven-segment displays
- Instead of using the buttons or switches of the FPGA board, build a digital interface for a PS/2 keyboard.
- Build an analogue filter to modify the shape of the square wave
- Instead of generating a binary signal, generate an 8 bit digital signal with different shapes. Therefore, this signal has to be converted to analogue.
- Performing any other digital processing to the audio.

A scheme of the electronic piano project including some of the enhancement proposals is shown in fig. 6.

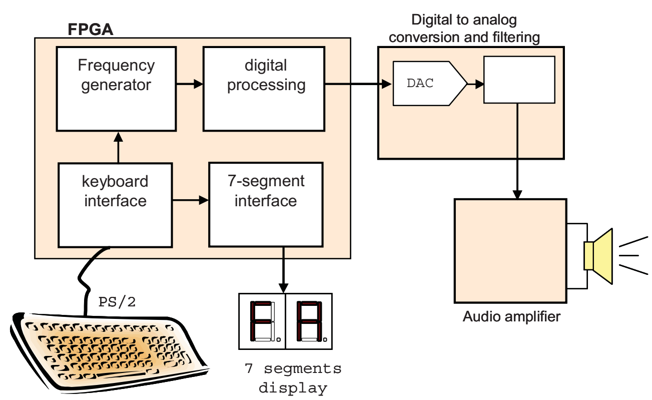

Figure 6: Proposals for the enhanced electronic piano project

B. *Electrocardiogram Project*

The electrocardiogram (ECG) project is a vertical project carried out by students of second (DE2), third (DES) and fourth years (ESCD and EI), see fig. 1. This project is more complex than the electronic piano project since it involves different technologies and requires a wider communication among the students, which, in addition, belong to different years.

As it has been stated, in these labs a basic project is first proposed to the students, but ideas are also given for possible enhancements.

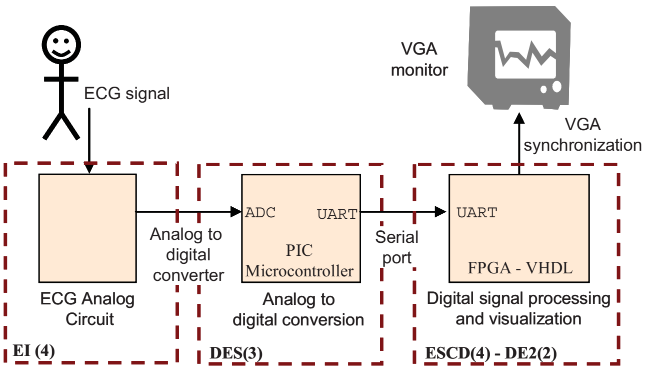

Figure 7: Basic ECG project

The basic project scheme is shown in fig. 7. In this scheme, the project has been separated in three blocks, corresponding to the different courses involved. These blocks are:

- ECG Analogue circuit: this block deals with the acquisition of the biological signal. It will be performed by students of Electronic Instrumentation (EI).
- Analogue to digital conversion: this block will convert the analogue signal into a digital signal. Students of Digital Electronic Systems will be responsible for building this block.
- Digital signal processing and visualization: this block will receive the digital signal from the PIC microcontroller and will show the ECG waveform in a VGA monitor. This block will be designed jointly by Digital Electronics II (DE2) and Electronic Systems and Circuits Design (ESCD) students.

The project has to be done in two stages because the course Electronic Instrumentation (EI) is taught during the second semester of the fourth year. Therefore, during the first stage, the students have to build the project considering that the analogue signal is already given (with an ECG emulator).

The project is coordinated by the students of ESCD. These students will assist the rest of the team helping them to define their block and the interfaces with the others. Later, in the second semester, ESCD students will finish the project building the ECG analogue circuit as part of their EI course.

As in the piano project, fig. 7 shows the basic implementation of the ECG project. Further enhancements are proposed as shown in fig. 8. These improvements include:

- Performing signal processing in the PIC microcontroller or in the FPGA.
- Showing the heart rate through a LCD or seven-segment display (using the PIC or the FPGA).
- Generate a sound every heart beat and amplify it with a analogue circuit. This enhancement would include students of AE, and would be similar to the electronic piano. The sound wave could also be generated by the PIC microcontroller.

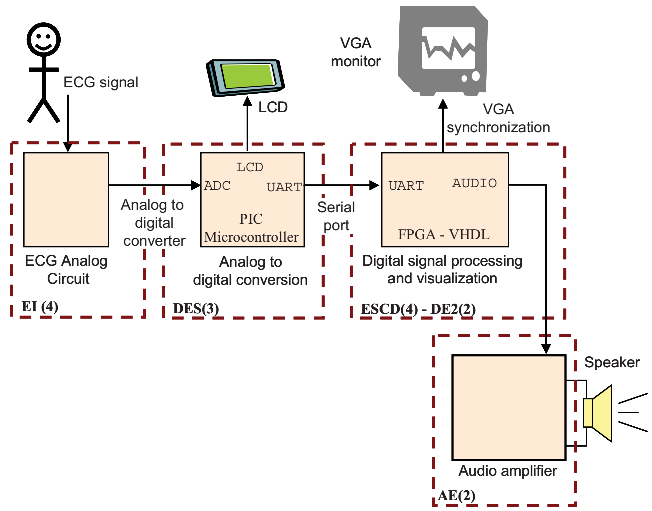

Figure 8: Enhanced ECG project

IV. RESULTS AND DISCUSSION

The proposed curriculum covers all aspects of analogue electronics (components, amplifiers, feedback, filtering, frequency analysis) with the ECM, AE and EI courses. Only some topics in communication electronics are not covered (PLLS, oscillators). Digital electronics is also thoroughly covered. Hardware description languages are covered in detail inDE1, DE2 and ESCD. Digital system design is taught through the DES and ESCD courses.

The curriculum has been evaluated taking into account the grades obtained by the students and their degree of satisfaction, as shown in official University surveys performed at the end of every course. Results show that students are highly satisfied with their training in electronics. Among the main topics pointed out in the survey we can highlight:

A. Teaching methodology

B. Course planning and organization

C. Are the contents of the course interesting?

Table 2 shows the student evaluation of the electronic related courses described in section II. Scores range from 0 (lowest) to 5 (highest). The mean of each topic is above 4 out of 5.

TABLE 2: STUDENT EVALUATION OF THE COURSES

	ECM	DE1	DE2	AE	DES	ECDS	EI
A	4.1	4.0	4.0	3.5	4.1	4.5	3.6
B	3.9	4.0	3.9	3.8	4.2	4.2	3.8
C	4.0	4.4	4.4	3.8	4.3	4.6	3.7

Regarding PBL among courses, both horizontal and vertical projects were carried out as an experimental activity.

We have observed that horizontal activities are easier to perform, as students belong to the same group and have previous experience working together. Vertical activities (integration of sub-project among student of different years) were harder to coordinate due to the different timetables, and degree of acquaintance. Around 15-20% of the students volunteered to participate in the special projects.

All horizontal activities were successfully accomplished in about four weeks, two weeks less than the time initially estimated. During that time, students worked mostly on their own, anticipating the concepts the professor explained in the regular lectures. Only in few occasions did they need the professor's advice. Additional skills inherent to the experimental work were acquired by the students, such as reading and comparing datasheet to meet project requirements and soldering in board. They even enhanced both by ideas proposed by the professors and by themselves. As an example, they proposed to store a melody in the FPGA. One of these projects is shown in fig. 9.

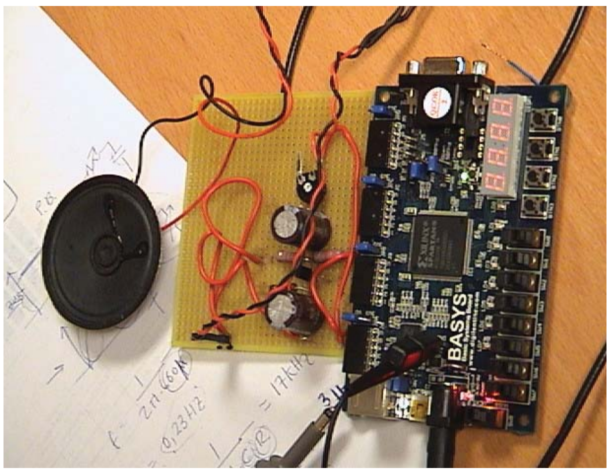

Figure 9: One of the resulting piano projects

Students that successfully completed the project, volunteered to present their work to the rest of the class. They prepared a fifteen minutes oral presentation and a live demo with the melodies stored in the FPGA. The response of the students that were not involved in the projects was of great enthusiasm, some of them expressing their will to join the project methodology next year.

In the vertical activities, two thirds of the groups completed their subproject, but they did not have enough time to integrate into the complete project. This was due to the difficulties in coordination among groups. However, all students intend to complete the integration along the next semester.

V. CONCLUSIONS

We have presented a project-oriented curriculum on Electronics for Telecommunication Engineers. These courses have been evaluated very positively by students. The consistent approach of this curriculum has allowed us to design project activities among different courses. This fact, together with the project orientation of each course, makes the transit to the Bologna Process easier.

The developed PBL activities among different courses have been received positively by the students. These projects provide students with skills and competences promoted by the Bologna Process, such as team work, initiative, responsibility and leadership. Participants have shown a high degree of motivation since many of the groups have finished before the assigned time and have performed many of the proposed enhancements.

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Training Microsystems Technologies in an European eLearning Environment

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Abstract—**The paper presents the ongoing activities within an European project for development of eLearning courses in microsystem technologies. It is a two-year project within the Leonardo da Vinci programme and the partners are from small and medium enterprises in microelectronics, training organizations and universities from four European countries – Romania, Bulgaria, France and Germany. The project is aimed at implementation of innovative approaches for performance–centred learning and development of new instruments in instructional design of task-performance-centred courses for education in Microsystems design and technology.**

Keywords-Microsystems technology education, performance-centred approach; e-learning, European project

I. Introduction

Scientific research, technological development and innovation are at the heart of the knowledge-based economy, a key factor in growth, the competitiveness of companies and employment [1]. "The shift to a knowledge based economy is of crucial importance to competitiveness and growth. Business and citizens in the EU have been slower in embracing this new economy than in the United States. The Lisbon indicators confirm that investment in the development and introduction of new technologies is behind the United States." [2] Micro- and today nanoelectronics is the most rapidly developing science. All specialists in the field need regular re-training. In this most rapidly developing science which represents the basis of the e-economy and the e-society the continuous training is crucial.

The shortage of engineers in micro- nanosystems and the systematic decrease of students in electronics at the university can be a threat to the European economy competitiveness. The informal Meeting of Ministers of Education and Ministers of Research in Uppsala underlined the importance of increasing recruitment to scientific and technological disciplines, including a general renewal of pedagogy and closer links to working life and industry throughout the whole educational and training system [3]. In many publications at the 3rd European workshop "Microelectronics Education" it was stated that "a new breed of engineers must be created and the way we create them has to change" [4] "from the classical engineering schools to multi-disciplinary research organisation - system design centres". So, a partnership between small and medium enterprises (SME) and universities for delivering training in Microsystems technology has crucial importance for the European competitiveness on the world market for electronic systems.

Additionally, it is important to be mentioned that Europe's electronics industry is increasingly moving east. Multinational OEM (Original Equipment Manufacturer) and EMS (Electronics Manufacturing Services, contract manufacturers) companies invested great amount of capital and built up high-tech plants in Romania during the last years. The reasons why Romania is an ideal investment location in Europe include, first of all, their well-trained, creative and flexible human capital, in particular highly educated engineers and skilled workers, accompanied by high productivity/wage ratio. Based on mSysTech project, the Romanian working force involved in micro-systems and related fields will have the opportunity to be in contact with the latest developments in these very dynamic fields and to have access to practice oriented, vocational training courses destined to the knowledge level.

Bulgaria has also strong traditions in microelectronics (in 1989 the foundry in Botevgrad worked on a technology of 2 μm which was the top technology at that time) and the last 5 years a number of new SMEs in the field are created (HIC, EPIQ, Milexis, Centillion, NanoToolShop, etc.) and MSysTech project is designed to meet their needs of qualified and trained personnel.

II. Rational of the Project

In the 21st century the high level research is increasingly complex and interdisciplinary; it is increasingly costly; high level research requires a constantly increasing "critical mass". Microsystems are developing on highest level of research and the continuous training is crucial. This project is aimed at adapting the existing and developing new courses for the lifelong performance support systems in microelectronic packaging and microsystems for the needs of the Romanian and Bulgarian SMEs, vocational schools and universities.

There are very few individual research teams or laboratories or companies that can reasonably claim to be able to respond to the technological challenges. In nano-era an integrated approach is needed, and interaction of innovative SMEs, universities and research organisations in the research and training actions and it is a key factor for strengthening the European RTD potential. The Internet courses within the mSysTech project will provide new opportunities for co-operation between vocational training institutions, universities and SMEs in the sharing of knowledge and educational resources: the distributed support system in four European countries created in the IPCI project will be enlarged with two new countries within the proposed project.

III. Objectives

This project is aimed at adapting and integrating innovative performance-centred training approach into engineering education and training organisations and SMEs in microsystems technologies. The focus is on the transfer of innovation in two new countries: Romania and Bulgaria and in the multidisciplinary area of microsystems. Its objectives are:

– identifying and analysing user requirements of managers, engineers, students and technical staff in the multidisciplinary science of microsystems technologies,

– selecting ICT-based innovative content to meet these requirements and analysing the feasibility of transfer of the performance-centred approach to train this content,

– adapting and implementing the e-learning environment with training materials with simulations, demonstrations to improve skills in microsystem technology.

– training the core user groups of training providers – teachers, managers and educational policy makers in the innovative learning approaches and in the effective collaborative use of new technologies in vocational education and training.

The primary target groups concerned are: students in engineering education and vocational schools, professionals from SME in electronics and Microsystems, educated but unemployed people (e.g. engineers, physicists) looking for additional training for employment.

IV. Implementation

The mSysTech project is based on the positive results and experiences in two European pilot projects: Leonardo da Vinci project “Internet-based Performance Centred Instruction – the Link between Work and Education” (IPCI) and Socrates/Minerva “On-line Learning Mathematics and Sciences”.

Within the IPCI project a complete set of courses covering microelectronics design, technology and packaging were developed. There are not many frameworks that unify these subjects in an attractive way. The performance centred approach has been proven to be more effective than the traditional lecture-practice-test (expository inductive) in training higher order skills, for preparing learners for self-learning, improving, adapting for changing tasks, jobs.

In mSysTech the performance-centred job-linked training approach will be used also and the selected content from the courses of IPCI will be adapted and up-dated for the needs of Romanian and Bulgarian electronic sector and education. The new learning materials on the Microsystems technology and the evolution of nanosystems during the last three years (after the end of IPCI) will be developed and used by all partners in the project, as well by the partners from the IPCI project who are not in the mSysTech partnership.

The project main result will be an e-learning environment with innovative pedagogical approach and the use of state-of-the-art multimedia materials to train the newest technological achievements in the sciences representing the basis of the e-Europe. It will provide performance support to the individuals undertaking self-directed learning.

The following courses are already developed:

- *Microsystems Design and Technology* by Institut National Polytechnique Grenoble, Centre interuniversitaire de microélectronique, NanoTech.

The objective of the course is to show the physical background and the approaches that are used in the design of MEMS-based sensors and actuators. The course gives an overview of microsystem technology and its applications. The course suits especially well for students who aim for R&D tasks. Following issues are discussed using examples of different MEMS devices design:

• Modelling and simulation of MEMS devices

• Different types of transduction processes used in MEMS

• MEMS based accelerometers

• MEMS based pressure sensors.

- *Packaging Technologies* by Politehnica" University of Bucharest, Center for Technological Electronics and Interconnection Techniques (Fig. 1).

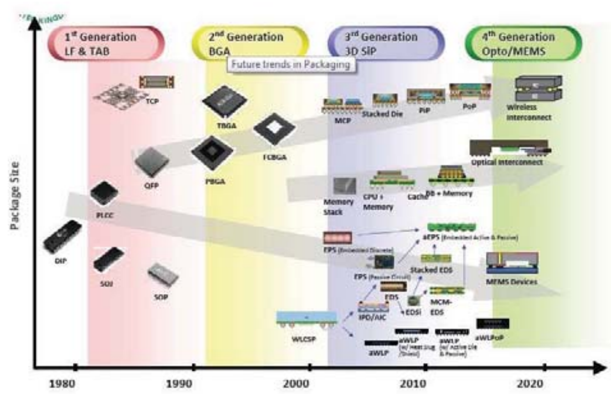

Figure 1. One image from the “Packaging Technologies” course

The objective of the course is to introduce the learners in microsystems packaging technologies, including design, analysis, fabrication, assembling, characterization and testing. In addition, this course introduces the most recent developments of micro-/nanofabrication technologies. The course covers the research and innovation in the following major topics:

• Fundamentals of microsystems packaging;

• Packaging Materials;

• Electronic design, CAE-CAD-CAM and EDA of microelectronic systems;

• Modelling and simulation of electronic/microelectronic structures;

• Assembling technologies based on RoHS & WEEE European Directives;

• Measurement, characterization and testing of microsystems.

- *Thermal Management of Microsystems* by the Technical University of Sofia, Department of Microelectronics.

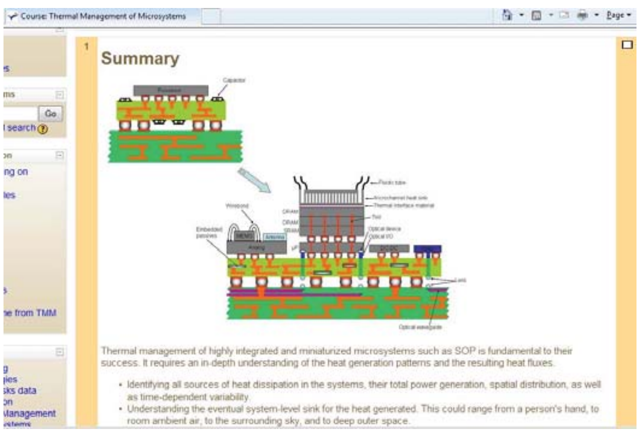

Figure 2. The “Summary” screen of the course “Thermal Management of Microsystems”

This course deals with effective thermal management of highly miniaturized system-on-package (SOP)-based systems (Fig. 2). The learners will be able to define the most appropriate method of design and packaging of different microsystems for effective heat evacuation and minimisation of the hot spot effect; to evaluate the reliability and to identify the possible defaults dues to overheating in order to insure the reliable functioning of the microsystem. The course covers the following major topics:

• fundamentals of thermal management of mycrosystems;

• thermal sources in systems on package (digital SOP, RF SOP, Optoelectronic SOP, MEMS);

• fundamental heat transfer modes;

• thermal characterisation: numerical methods for thermal characterisation; evaluation of thermal analysis software for Microsystems; experimental methods for thermal characterisation;

• thermal management technologies: passive methods of thermal management (high-conductivity package materials, thermal vias, heat spreader, extended surfaces, heat pipes [5]); active methods of thermal management (liquid loops, spray cooling, thermosyphon, thermoelectric cooling, thermionic cooling etc.);

• power minimisation technologies.

- *Photomasks Data Preparation* by Xyalis Ltd, Grenoble.

Main goal of this course is to present the techniques used in micro- and nanocomponents photomask data preparation. This course will allow to fully understand all the issues related to this critical step of chip development as well as the methods used to reduce both costs and delays. The course introduces the basics of photolithography and the various types of masks used. A detailed description of the multiple constraints and of all the patterns required on masks is provided:

• process control modules

• measurement structures

• alignment marks

• identification patterns

• chips

The different steps of mask data preparation will be explained:

• input data manipulation, validation, fracturing, OPC (optical Proximity Correction)

• assembly of various devices

• constraints and optimization

• inspection techniques

• repair techniques.

Figure 3. The module on MEMS mask data preparation

MEMS related issues are detailed (Fig. 3). The last module gives an overview of advanced research and state of the art in photomask development.

The courses available on Internet will improve the accessibility of the learning materials and the delivery of training in all contexts: at home, in the university or vocational school, and the most important - on-the-job.

V. THE APPROACH

Focusing on learning or knowledge transfer rather than performance results in people who know what to do but never do it [6]. Learning technologists must recognize that their jobs do not end with training. Learning must be turned into performance, shared with the entire organization, then cycled back into the next iteration of training. Learning technologists must take an interest in - if not responsibility for - the full cycle. They need to embed performance support and knowledge sharing into learning activities so they become second nature to the learners/performers.

So, in our project we decided not just to design an improved training but to perform a performance-centred design. The performance-centred design transforms knowledge into performance by creating an interface to the knowledge base. In the design we followed the principles, determined by Rosenberg [7].

Performer-Centred Design. A key difference between performance support systems and training systems is the locus of control. In training systems, the author takes the role of expert and sets the rules for working and the criteria for success. In a performance support system, we must recognize the performer's expertise in his/her environment and the fact that the performer may have additional information not contained within or considered by the support system. Our system, therefore, takes the role of an assistant rather than a director.

Learn by doing. Much of what we know to do in a job we learn on the job. One of the responses of the training community has been to provide just-in-time training or on-demand learning, so as to situate the training in the job environment at the time of need. This direction has great merit and no doubt will benefit development of work competencies, but I suspect that the greatest limitation of training is its abstractness. Merely changing the time and place will not make it contextually appropriate. Our learning and support systems need to increasingly model apprenticeships rather than simply serve as information distribution systems.

Apprenticeships embed the learning of skills in their social and functional context and make the "what is learned" more meaningful and valuable. A performance support system should encourage workers to try things that stretch their knowledge and skills.

Organizational Memory. Organizational memory refers to the knowledge that an organization has or could have about its business and to the process it uses to acquire and recall that knowledge. It includes what is archived in electronic and paper documents, but even more critically, what people in doing their work have learned. How often have we been in a situation where we need to know something and instead of looking it up in books or other archives—we call someone?

Our support systems should aspire to mimic the knowledge base and process for acquiring expertise that is used by practitioners. Thus, the process needs to be on-going, rooted in practice and experience, and constantly adjusted by new inputs. We need to find ways to capture and share expertise. So, in the reported Web-based performance support system the knowledge base is the core component.

Technology Use. The performance support system (PSS) is a natural extension of building technologies that transform the way people work and learn. The technologies of performance support help people be connected when they are mobile [8], be competent when they are inexperienced, be reflective when they are hurried, and be resourceful when they are challenged. Our system is Web-based.

VI. HOW INSTRUCTION IN PSS IS DIFFERENT FROM TRADITIONAL COMPUTER-BASED TRAINING

Computer-Based Training (CBT) systems are often set up to enforce the sequencing of sections determined by the task analysis [9]. The enforcing of the sequencing relies on the system keeping learner's records. The system checks the learner's record to determine if the learner has completed the required prerequisite sections satisfactorily before allowing the learner to enter a new section of the lesson.

In PSS enforcing the viewing of prerequisite is not present. It is up to the learners to determine if they need to review the prerequisites. Links to the prerequisites are provided, but viewing them is not mandatory.

Learner's records should not be kept, if at all possible. One of the main purposes for keeping learner's records is to enforce the sequencing of instruction. Because the learners choose their own sequence in PSS, there is no need to keep learner's records for sequencing purposes.

Lesson segments are as small as possible. In PSS, the learners usually enter the instructional component to learn a specific task. The lesson segment should only cover that specific task. If the lesson component covers more information, the learner takes longer to complete the original task.

Lesson segments are self contained. The instructional developer should try to limit the dependence on other lesson segments, because there is no guarantee that the learner has viewed the other lesson segments. The instructional developer should try to minimize any undefined acronyms and backward reference.

It is easy for the learner to use the instructional component. We don't make the learner sign in to the instructional component, and we allow the learner to escape from the training at any point.

The primary targets groups of mSysTech system are the students in engineering education and colleges, who need education related to their further work, learning competencies necessary for the workers in an 'intelligent organization'. So, the instruction in the training modules is designed following the PSS technology.

VII. Project Outcomes and Innovation

The main expected outcomes of the project are:

- System for on-line course development with a performance support system (PSS) for developers;
- Virtual Performance Centred Environment for Training in Micro- and nanoelectrinics, and Microsystems technology;
- Training materials for 3 courses in microsystem design and technology, packaging and thermal management; Internet-based tutorials;
- Database to facilitate access to training and professional realisation of women in the sector of micro- and nanoelectronics, and microsystems and to provide equal opportunities for women and men.

The innovation contributed by this project involves:

- new approaches to the use of existing methods: distributed performance support system

The project considers the concept of a performance support system from a new theoretical perspective in where distributed cognition and distributed learning are underlying concepts. Learners have opportunity to interact not only with particular content but also with peers, instructors and other experts.

- new products in response to existing problems: training courses in Microsystems technology

The courses are developed in response to the training needs described above.

- new processes: distributed learning

Distributed learning rather provides new perspective and dimensions of the classical distance learning concept. *Distributed learning* in the context of PSS does not ignore the importance of organising learning content and its sequence, but emphasises on creating a learning environment that enables an interaction with learning resources, peers, instructors, and external experts, located at different places, with no time constraints. Learners gain a greater control on constructing their learning. Distributed learning changes the role of the instructor from knowledge transmitter to coach or facilitator.

- new forms of co-operation between partner organisations: distributed curriculum.

The idea for distributed curriculum or a Virtual Technical University is not so novel. For example in USA the National Technological University is providing distance engineering education with distributed curricula, i.e. the departments from different universities which are the best in some area develop the corresponding course and it is delivered in a common curriculum in one virtual university.

In the proposed project we will apply the same approach in the development and delivery of the distributed curriculum in microsystems with the difference that we will involve not only training organisations but the main users as developers – the SMEs. The notion of distributed PSS introduces the concept of *distributed instruction* as well. It applies embedded content management facilities with tools, templates, and guidelines for designing courses from reusable learning objects in a shared repository. The *mSysTech* is an open course initiative with an attempt to build a case of good practice based on the collected experience.

VIII. Summary and Conclusion

In this manuscript we presented a work in progress within the European Community project "e-Training Microsystems Technologies". The project is aimed at implementation of innovative approaches for performance–centred learning and development of new instruments in instructional design of task-performance-centred courses for training in microsystems. At this stage in the project lifecycle we have already developed the IPCI environment with its main components, and with an integrated environment for the training materials development. Four courses are being designed and the learning materials of three courses are under development by the teachers.

As a new technology, IPCI will move the traditional teaching systems to the closely related to the job learning. In this point, these systems have a strong potential to help students mastering job-related skills. The message to the teachers, to consider the impact of teaching on results, good performance and competitiveness, is another perspective of this innovation.

As happens with most new technologies, some people will promote PSSs as the answer to all problems. But like most technologies, PSS has its limitations. If the improvement in employee's performance in corporate setting thanks to the PSS is already proved, for the students there are some doubts and we have to study the effectiveness of this approach in the university context. And we expect to learn more about the effectiveness of this approach through experiment planned for the pilot test.

ACKNOWLEDGEMENTS

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Session 01C Area 1: Collaborative and Social Technologies - Social Computing

OER´s production cycle with social authorship and semantic tools

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Meta-analysis of the TAEE project applying social network analysis

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Social Media Enhanced Studying and Learning in Higher Education

Silius, Kirsi; Miilumäki, Thumas; Huhtamäki, Jukka; Tebest, Teemo; Meriläinen, Joonas; Pohjolainen, Seppo

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Three Online Neutron Beam Experiments Based on the iLab Shared Architecture

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OER'S Production cycle with Social AuthorShip and Semantic Tools

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Abstract— **Open Educational Resources (OER) are digital content that are accessible through web repositories. They are used as support tools for education, especially for higher education, and they promote equality and social justice by providing access to, applying, and generating knowledge. Until now OER's have been developed from the pedagogic perspective, without taking advantage of the recent developments in communication technologies.**

Integration of social tools improves the active participation of both the developers and users of the OER's. This promotes the rapid creation of content that is easily accessible via search engines linked to educational platforms and social networks. It also allows *tagging*, which gives users the ability to add descriptive metadata. Authorship is recognized through the use of intellectual property licenses that promote open use of the material so that it can be used and edited. And above all collaborative learning is promoted.

In this article a new cycle of OER production is proposed that includes activities to incorporate social networks and semantic technologies. The phases of the production cycle are developed using the ADDIE instructional model. The purpose of each phase and the social and semantic components to be included are identified. And finally, application guidelines are presented that detail the strategies and expected results for each phase of the proposed cycle.

We have determined that the primary reasons for developing a production cycle for OER's using social authorship are: to allow educators and students to develop resources collaboratively; to reduce the amount of time spent in resource development; and to provide for reutilization of quality OER's. Finally, it should be recognized that the success of the model and its application depends on the institutional context where it is implemented, as well as the policies related to content generation, authorship acknowledgement and distribution of the resources.

Keywords-component; Open Educational Resource; Social Authorshi;, Semantic Web; Collaborative Learning.

I. INTRODUCTION

Open Educational Resources (OER) have been identified by the Flora Hewlett Foundation, one of their primary supporters, as a means of providing equal access to knowledge worldwide [1]. For this reason, many universities throughout the world are involved in these types of initiatives. These initiatives have also raised the interest of international organizations who are working to develop a framework that will assure accessibility, usability and quality of the content and structure and tools utilized to produce OER's.

The Web 2.0 allows users to actively participate in the development of knowledge through the use of tools such as blogs, wikis, RSS, social networks, microblogging, etc. The Semantic Web is the web of data, that is, it incorporates meaning through the use of semantic metadata and ontologies and allows users to find results more quickly and easily.

OER development would be enriched by the features offered by the Web 2.0 and the Semantic Web. These features can be integrated into the production cycle to promote collaborative learning between producers and consumers of resources during both development and implementation. Also, the use of tagging and other semantic technologies optimizes the detection, identification and dissemination of OER's. This proposal also supports the use of Creative Commons licenses for authorship recognition, which should be adapted to the individual policies of each institution.

II. TRENDS IN OER´S

The evolution from a static web to a social and participatory web, with its many manifestations that have gained great acceptance among internet users, provides an opportunity to utilize social software as an e-learning method, to develop the skills and capabilities needed in the knowledge society (the abilities to analyze, synthesize, communicate, and resolve problems, among others).

OER's – resources that provide educational content with an open license that facilitates their use, adaptation and modification – have become key elements for higher education. UNESCO refers to them "web-based materials that are freely available for use in teaching, learning and research" [1]. The Creative Commons licenses allow content and resources to be open and free, in this way favoring open access to knowledge for the benefit of society and at the same time promoting the development and use of OER's.

The William and Flora Hewlett Foundation has supported many projects in this area because of their great potential and their contribution to the development of education. Due to the fact that there is a great quantity of educational material available on the web, but that is poorly organized and therefore does not contribute to quality instruction, the OpenCourseWare (OCW) projects have been developed.

In 2001 the Massachusetts Institute of Technology (MIT) launched the first OCW initiative offering complete courses with study guides developed and utilized by their educators. The guides were freely accessible and distributed on the internet; their use, re-utilization, adaptation and distribution was permitted, with certain restrictions determined by the licenses assigned by the authors. Hundreds of universities have joined this initiative and have made their materials available to professors, students and laypersons world-wide.

The evolution of the internet includes four phases: the Web 1.0 develops an information network; the Web 2.0 creates relationships between people through social networks which promote collaborative knowledge; the Web 3.0 includes representation of meaning, connection of knowledge and improvement of the internet experience; and the Web 4.0, which is yet to be developed, that involves the connection of intelligence in an ubiquitous and universal Web. [3]

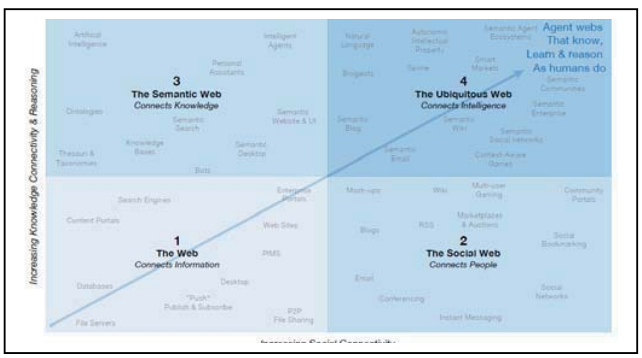

Figure 1. Internet Evolution [3].

The Social Web is driven by those applications that gain value through the actions and participation of their users; it is an attitude not just a technology. In this environment it is possible to gather, distribute and share individual actions within a social context, using tools such as wikis, blogs, microblogging, RSS, messaging, and social networks (Figure 2).

The social web allows the user to participate actively as an author in the knowledge society, and this includes the development, management and distribution of knowledge in a collaborative manner. These activities generate collective intelligence that accompanies the learning process, promoting the development of skills among the participants adapt to the process through open and free discussion opportunities that stimulate creativity, critical thinking and social and communication skills.

Figure 2. Social Tools [4]

In the production of OER's it is necessary to include semantic components to exploit the aforementioned resources.

Since OER's are found on the Web, they are becoming part of the Semantic Web (which gives meaning to all types of information available on the Web). According to [5] the Semantic Web has unique properties that facilitate the development of OER's:

- Improves discovery and storage in local and global databases, and therefore OER's should have semantic information (metadata) to simplify their discovery and re-utilization.
- Promotes the use of ontology that highlights the structure of the resources to assign pedagogic meaning, and
- Strengthens the personalization of educational content and the development of resources to assist the user with significant tasks in the Semantic Web.

The basic semantic technologies that should be used are:

Unicodes1 and URIs2 to identify web resources.

- XML 3 : To present, manipulate, and transmit structured data and documents.

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1 UNICODE: http://www.unicode.org/

2 Naming and Addressing: URIs, URLS. (http://www.w3.org/Addressing/).

3 eXtensible Markup Languague (XML). (http://www.w3.org/XML/

- RDF4: Provides a model of common data, based in XML NameSpaces, which is used to formalize metadata.
- Educational Ontologies: Used in web-based teaching. [6]
- Ontologies related to the physical structure of the object: So that the OA can be interpreted and utilized in different teaching systems. DAMP5 and OIL6 are used for the development of ontologies.

Social repositories facilitate the storage of resources that are available for users to share on platforms that permit them to download, tag, vote and comment on these materials.

III. OER Production Cycle

An OER is the result of a production cycle with many intertwined phases. Each phase has its own specific purpose and is carried out in a generally sequential manner. Throughout the process the needs of the education community are considered and active participation is promoted.

Normally the development of these materials involves the use and reuse of digital resources such as videos, text, and images, which are considered by many authors to be digital content and information objects. This process also involves the development of metadata associated with these objects, which allow them to be stored, catalogued and searched in data repositories, as well as provide information about copyrights that can be used to determine if the content may be consulted, utilized or edited.

An analysis of several OER production cycles was conducted and the common denominator found was the use of standards for packaging and for metadata. These standards are shown in the following table:

TABLE I. Comparision Of University OER Producion Cycles

University	Methodology	Packaging	Metadata	Storage or Implementation
Universidad Técnica Particular de Loja (Ecuador)	Based on the principals of LOSADA	SCORM	LOM	DSpace
Universidad de Aguas Calientes (Mexico)	AODDI, based on the instructional model ADDEI	SCORM	LOM	MOODLE
Politecnica de Valencia (Spain)	Via the use of models	SCORM	LOM	Agrega Ruinet
Universidad de Burbula de Venezuela	ADDIE	SCORM	LOM	MOODLE
Politécnica de Madrid (Spain)	TAEE	SCORM	IMS Metadata 1.2.2	MOODLE
Universidad de la Sabana (Colombia)	(Instructional model in learning objects)	SCORM	LOM	MERLOT

4 Resource Description Framework (RDF).(http://www.w3.org/RDF/

5 DARP Agent Markup Language (DAML). (http://www.daml.org/)

6 Ontology Inference Language (OIL). (http://www.ontoknowledge.org/oil/)

This comparison of the OER cycles employed by the previously mentioned universities shows that the majority of these institutions use the ADDIE instructional model. This model is favored because it includes characteristics such as feedback and continuous review, and because it is the most widely-used model in educational contexts.

Instructional Design is a method that defines the steps to take in the process of evaluating student needs, designing the project, developing the educational materials, and evaluating the effectiveness of the OER's in the learning process.

There are more than 100 different Instructional Design models but they are all based on the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model. Each phase of the model produces a result that provides information for the following phase. When the "Revision" phase is added to the process the model is called ADDIER.

The activities performed in each one of the phases of the ADDIE instructional model are described below:

- **Analysis:** The instructional needs (lack of knowledge), the audience, the learning environment and the technical infrastructure are analyzed.
- **Design:** The content and structure of the OER's are defined and categorized.
- **Development:** The development of the OER's, which includes quality control and storage.
- **Implementation:** A strategy is selected to integrate the OER's into a product, and a management and follow-up plan is created.
- **Evaluation:** A comprehensive evaluation is conducted to determine the impact that the OER's have had on the teaching process.

Most Instructional Design models are based on the ADDIE model, which is why the OER production cycle with social and semantic components proposed in this article is based on the ADDIE model.

Furthermore, there currently exist many data repositories that include semantic metadata, such as:

TABLE II. Open Educational Repositories

Project	Number of resources
CAREO	4 137
MERLOT	14 376

Project	Number of resources
EdNA	28 471
DLESE	11 864

IV. OER Production Cycle With Social Authorship

For OER's to be created with social authorship it is necessary to develop them in a collaborative manner, using collaborative learning techniques. This process is becoming a common practice within different disciplines.

Johnson and Johnson, in 1998, defined collaborative learning as "a system of interactions carefully designed to organize and promote reciprocity between group members." Collaborative learning is achieved by implementing methods to promote working as a group, which are characterized by the interaction and support between the members of the group for the development of knowledge.

Longmire [7] mentions that "the challenge faced by those that develop educational objects and the repositories to store them is not only to provide the possibility of finding educational content, but also to provide relevant and significant contexts for the students that locate the content." This thought is, without a doubt, applicable to OER's because of the need to incorporate semantic components that provide significant context to the resources and allow them to be located and utilized within the growing supply and demand for web resources.

There are several key characteristics that OER's must possess, and their existence must be guaranteed in the production cycle, as shown in Table 1. Tools exist to evaluate these characteristics, such as the Learning Object Review Instrument (LORI), whose results promote the proactive development of learning objects and support those who actively participate in their development [2]. It is thought that LORI can be a valuable support for the evaluation of OER's.

TABLE III. BASIC CHARACTERISTIC OF OER'S

Characteristics	Brief Description
Quality Content	Precision, veracity, adequate level of detail, balanced presentation of ideas
Alignmen t with objectives	Alignment with the objectives for which they were conceived
User interaz	Visual design that facilitates learning and mental efficiency
Reusability	Educational resources that are usable in various contexts
Accessibility	Design of elements in formats that permit access from other media
Interoperability	Guarantees the exchange of content

In order to produce OER's with the abovementioned characteristics, the proposed production cycle is focused on providing flexible and usable resources. If an opportunity is identified during any one of the phases, ideally during the evaluation phase, the analysis phase should start again and the process should be repeated with the objective of developing a new version or a new meaning for the resource.

For the proposed social OER production cycle the five phases of the ADDIE model have been modified to include specific tasks. For each one of the phases a social and semantic component is proposed depending on its specific purpose.

1. Analysis:

- ***Purpose:*** Identify the needs to be addressed by the OER. What needs to be produced?
- ***Social component:***
    - o Use existing social tools such as blogs, wikis, social networks, and microblogging as a source of information by which the users communicate their needs and expectations regarding their education and training.
    - o Document the analysis using tools such as wikis, blogs and Google Docs.
- ***Semantic Component:*** Identify terms to associate the OER with metadata.
- ***Application Guidelines:***
    - o Utilize social tools (blogs, wikis, social networks) within specific courses or subjects.
    - o Allow students to fulfill course requirements by means of social tools.
    - o Tabulate suggestions for improving the course using collaborative tools such as Google Docs and the subject blog.
    - o Identify the primary metadata.

2. Design:

- ***Purpose:*** What? Who? How? Define objectives, content, structure, categories, metadata, policies and licenses
- ***Social component:***
    - o Use social tools such as wikis, blogs, and Google Docs which provide an opportunity for designers, experts, educators, academics, students and technical personnel to effectively participate in the process of defining the objectives, base content, structure, categories, metadata and policies of the OER.
    - o Provide opportunities for feedback on proposed definitions.
- ***Semantic Component:*** Define metadata for the resources.

- ***Application Guidelines:***
    - Redefine objectives, basic content, structure, categorization systems, metadata and policies taking into consideration the issues raised during the Analysis phase, as well as the possibilities offered by the Web 2.0 and the Semantic Web.

3. **Development:**

- ***Purpose:*** Implement the design, search for content resources, storage and quality control elements.
- ***Social Component:***
    - Search and locate resources using social tools, considering the value associated with each resource, comments, and number of visits.
    - Use social defined metadata (folksonomies) to locate available resources.
    - Find and develop resources in accordance with the characteristics defined in the design phase such as interoperability, re-utilization, and re-mixing.
    - Use functionality the Sharable Content Object Reference Model (SCORM) [7] ; metadata definition, metadata specification in XML and packaging.
    - Reload Editor
- ***Semantic Component:*** Linking metadata utilizing folksonomies and ontologies.
- ***Application Guidelines:***
    - Inventory social tools within the university.
    - Select appropriate resources in regards to subject matter, visual quality
    - Adapt or create specific resources for the course.

4. **Implementation**

- ***Purpose:*** Integration and management of the resources.
- ***Social Component:***
    - Use social recommender systems to link and integrate the resources with other related resources and repositories.
    - Distribute resources using social tools such as microblogging and social networks, and make the resources more accessible by including RSS and other technologies related to this purpose.
    - Apply the SCORM runtime environment guidelines, sequencing and navigation.
    - Associate the resources with reputation systems, version control, and feedback and monitoring systems that improve management activities.
- ***Semantic Component:*** Link the folsonomy or ontology to the network.
- ***Application Guidelines:***
    - Use RSS feeds to link other related educational resources with the institution's OCW.
    - Use social tools to distribute new resources.
    - Use reporting tools to track the number of visits to course resources.

5. **Evaluation:**

- ***Purpose:*** Monitoring, control, improvement of the resources.
- ***Social Component:***
    - As with the creation and distribution of the resources, evaluation and feedback will also be conducted by the users using social tools. The users will be given the opportunity to communicate whether the resources fulfilled their expectations and to provide suggestions for improvement through their comments.
    - Rubrics will be used to determine the quality of the resource using a scale based on parameters that the user considers pertinent.
- ***Semantic Component:*** Effective access to the resources in relation to their significance and context.
- ***Application Guidelines:***
    - Use the course blog to solicit feedback from students about new resources posted on the institution's OCW site.
    - Evaluate materials from the Information Fundamentals course.
    - Implement version control through a shared Google Docs document accessed by educators and the team responsible for the current cycle's proposal.
    - Utilize reporting tools to track the number of visits to course resources.

The figure 3 is a representation of the phases of the model, with the social and semantic components included.

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7 http://www.adlnet.gov/adlnews/Documents/News%20Archive/ADLReac hesAgreementwithIMSandIEEEonUseofSpecificationStandardsWorkinSCORM%C2%AE20043rdEdition.aspx

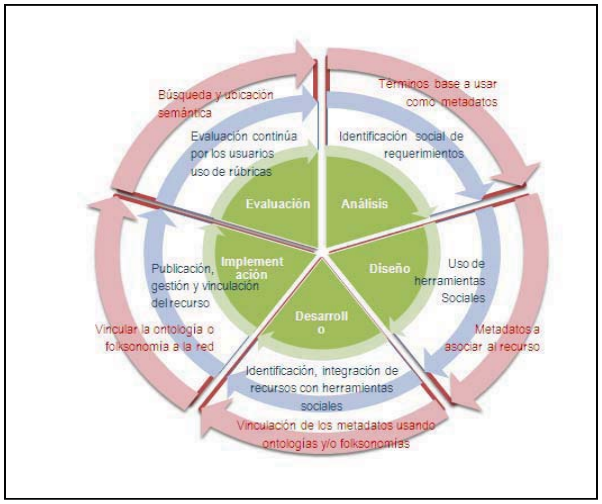

Figure 3. OER'S Production Cycle considering social and semantic components

The production cycle should adhere to the fundamental principles of Open Educational Resources – the resources should maintain an educational focus on developing the knowledge, skills and abilities of the users and they should be publicized using the appropriate legal framework within the Creative Commons licenses and its principal variations: Commercial/NonCommercial, ShareAlike, and NoDerivs:

Attribution or Recognition

Recognition and Share Alike

Recognition and no derivative works

Recognition and Noncomercial

Recognition Noncomercial and Share Alike

Recognition Noncomercial and no derivative works.

V. Application Of The OER Production Cycle Using Social Authorship AndThe Semantic Web

To complement the proposed OER production cycle using social authorship and semantic tools the following is a discussion of the expected results from each phase of the proposal, followed by a brief case study:

1) **Analysis Phase:**

- ***Purpose:*** Identify the need to be addressed by the OER. What needs to be produced?
- ***Expected Results:***
  - Social tools (blogs, wikis, social networks, among others) implemented.
  - Student requirements tabulated and organized.
  - Suggestions to improve the course gathered.
  - Metadata defined.

2) **Design Phase:**

- ***Purpose:*** Why? For whom? How? Define objectives, content, structure, categorization system, metadata, policies and licenses.
- ***Expected results:***[8]
  - Course structure and components reviewed.
  - Objectives and course structure redefined.
  - Resource types to be included identified and categorized.
  - General, specific and social metadata taxonomy established.
  - Metadata management strategy developed.

3) **Development Phase:**

- ***Purpose:*** Find resources for content, storage and quality control
- ***Expected results:***
  - Resources are identified.
  - Measurement tools for resource evaluation (criteria, values) are identified.
  - Resources are selected.
  - Necessary resources are created or adapted.

4) **Implementation Phase:**

- ***Purpose:*** Implementation and management of the resources
- ***Expected results:***
  - New structure and components established, resources designed and implemented.
  - RSS established linking other open educational resources related to the course within the platform in which it is implemented.

8 Not all results are required in this phase will depend on the identification made

- New resources are distributed using the social tools of the course.
- Tracking tools for the course and resources are implemented.

5) **Evaluation Phase:**

- ***Purpose:*** Assess and improve resources
- ***Expected Results:***
  - Feedback from users on the course and its resources obtained.
  - Results from the course evaluation system obtained.
  - Versioning of the Google Docs documents shared between educators and the work team completed.
  - Reports from course tracking tools obtained.

The OER production cycle using social and semantic tools was implemented in a course that is posted on the UTPL's OCW site. The process made use of the application guides previously described. Below is a summary of the process:

The course entitled "Information Fundamentals" was selected because it is one of the first courses available through the UTPL's OCW project and because the course instructors were available to implement the production cycle. In the analysis phase a blog was created (http://blogs.utpl.edu.ec/fundamentosinformaticos/); and subsequently the course requirements were obtained via the blog and the UTPL's Virtual Learning Environment (EVA). During the process of information collection the students suggested in increase in the utilization of social tools and other resources (videos, presentations, and additional documents) in order to improve their active participation and to support the theoretical portion of the course. In response, the instructors were asked to revise the course outline and redesign the course structure so that social tools could be utilized more readily, and to allow linkages to resources other OCW sites that could be reused and/or revised and adapted to the course. Also the first metadata were identified.

In the design phase the objectives and content of each section of the course were redefined by the instructors, taking into account the information obtained during the analysis phase as well as the suggestions from the work team responsible for the OER social production cycle. Thereafter, the resources were categorized by type and subject. Three types of metadata were identified according to their role. These metadata were used to create a unique taxonomy for the Information Fundamentals course within the Schools of Science and Computation. These metadata were managed by including them in all of the course's social tools; they were classified using the system previously described. They are governed by the UTPL's institutional policies regarding academic OER production, and they must conform to these policies.

In the development phase the taxonomy defined in the previous phase was utilized to search for resources using the OCW search engines. The resources were evaluated by applying the designations "Very Good", "Good" or "Average" to different criteria. After the resources were evaluated it was suggested that only those with all criteria qualifying as "Good" or "Very Good" be utilized, and those with criteria qualifying as "Average" be discarded. The last step of this phase was to adapt and/or create resources.

In the implementation phase the resources produced in the development phase were combined. RSS feeds from Information Fundamentals courses from external OCW sites were linked via the RSS feed portlet. The new resources were distributed via the EVA social network and the subject blog.

In the evaluation phase the course blog was used to acquire new information; the resources of the Information Fundamentals were evaluated. Also, a Google Docs document was created to share ideas between instructors and the proposal team to obtain feedback from the students, and report tools were used to track visits to the course resources.

As shown in Figure 3, the proposed production cycle is circular and the evaluation phase serves as feedback for the next production cycle.

VI. Conclusions

The following points have been identified as a result of this study:

- Although ADDIE is a linear instructional model utilized for production cycles of various types of resources, in the case of OER's it is necessary to include evaluation and quality control components within an educational context.
- Including social components in the OER production cycle facilitates collaborative learning between teachers and students.
- Web 2.0 tools improve OER searches by using their semantic meaning, and improve the evaluation of the quality of the educational content by reputable systems.
- The OER production cycle with social and semantic components reduces the time needed for development of these resources since available resources are being re-utilized and are available via social tools.
- Including social and semantic components in OER production is without a doubt an opportunity to take advantage of the benefits of these new web-related trends that provide pertinence, relevance and meaning to the resources.
- The success of this Model depends on the institutional context in which it is implemented, as well as the policies of content generation, author recognition and distribution of the resources.

- The use of social tools with resources is an improvement, but it has been observed that the time needed to access the resources increases for those users with slow connections.
- With institutional support, and especially that of the instructors, the production cycle will not produce the expected results.
- In the development of OCW courses, the use of other OER's is feasible because there are many quality educational resources available that can be reused in other contexts.
- When adapting existing OER's, quality assessment is an important activity for the optimal production of resources.

ACKNOWLEDGMENT

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Meta-analysis of the TAEE project applying social network analysis

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Abstract— **The social network analysis (SNA) is an approach that can be applied as a complement to other analysis (such as statistical) in order to obtain other valuable information. The social network analysis has been used in several initiatives showing that it is an approach that can contribute in building the semantic web. Within the project Technologies Applied to Electronics Teaching (TAEE) there are biannual conferences (it has been organized since 1996) and have accumulated a significant amount of data resulting from the conferences held. All of this information constitutes a data source that should be exploited and that can provide meaningful information. In this document we describe, how to social network analysis has been used on data sources generated by user communities, in order to obtain some semantic artifacts, like ontologies. Also describes how to was applied the social network analysis and its metrics on the information generated in the TAEE congresses to answer a set of questions (What are the relationships and the level of cohesion of the different organizations (at the level of Spain and across continents) involved in TAEE? How have evolutioned the thematics covered in the conference?, What are the new ontological additions in technology over the years?, and How have evolutioned the thematics in the research and studies related to teaching electronics?) formulated by the organizers of the congresses and that through other approaches would have been a large task and complicated. The answers to the questions can provide us important information about the behavior and characteristics of the elements present in TAEE conferences, furthermore being an element for making decisions on future initiatives with the same style of TAEE.**

***Keywords-** SNA, meta-analysis, TAEE, metrics, results, RedOBER*

I. Introduction

The social network analysis (SNA) is an approach used to find not evident information within the structures formed by the interaction between user groups or entities. The less evident information is the basis for finding patterns of behavior that provide additional and relevant information about the operation and characteristics of a network of some kind. The Social networks analysis covers areas such as: conflict of interest, criminal's networks, finding influential individuals, and study of co-author's networks, among others.

Since a few years ago the social network analysis has been used in several initiatives that have selected as data source the content generated via Web 2.0 tools and have developed networks in order to apply concepts of social network analysis and find a starting point on the road to the Semantic Web, showing that the semantics can emerge from user communities and through simple actions such as tagging. Other initiatives have proposed expanding the Query Language for the Semantic Web (SPARQL) with some concepts and metrics of social network analysis to enable the discovery other types of relationships, derived in a context, which they have called semantic associations.

The project of Technologies Applied to the Teaching of Electronics (TAEE) is an initiative involving several educational organizations and companies from Europe, North America, Central America and South America. The aim of TAEE is implement massively new technologies to the teaching of electronics. Since 1996, a biannual conference has been organized by TAEE project that talks about technologies for teaching electronics and whose aims to disseminate results of projects and initiatives in the areas of educational innovation and application of new technologies in teaching electronics.

The articles of the TAEE's conferences have been classified into large ontological families such as: Systems, Devices and Components, Instrumentation and Measurement, Automation, Robotics, Laboratories, Educative Software, Teaching and Construction Techniques, Implementation and Practical Realization. The documentation generated by each article in each conference is a data source to be exploited. To date there are; 964 documents, 1348 unique keywords, 1092 participating entities, and 1674 authors, among other data.

The aim of this paper is to show the results of the meta-analysis of the TAEE project's conferences (from 1996 to 2008) by applying social network analysis. Through some techniques, metrics and indicators of social network analysis was answered a set of questions that were asked by organizers of the congress and that are of your interest. Also was used to show some relationships such as the use of keywords in the description of the themes and the sub-structures that form between the co-authors of the documents. The metrics and indicators were used thus: to study the connections and distances between actors were used degree of a vertex and density, to determine the power and centrality of an organization were used degree centrality, closeness and betweenness, furthermore to analysis thematic and keywords, weight networks were used, Hubs, Authorities, and to study relations between co-authors k-cores was used.

The results obtained by applying social network analysis on the congresses of TAEE project unlike other analysis (such as statistical), has permitted us to: see graphically the relations between the different participants as well as the development of ontological families. Likewise, the task of finding isolated organisms and those organisms that serve as a link or bridge with others went simple, and showed the way in which they have been used keywords in different ontological families.

The paper is structured as follows: in the first section, we will discuss the social network analysis, its importance and its implementation in some projects of Semantic Web. The next section will be devoted to the TAEE Project's data source for meta-analysis. The third section will show the application of social network analysis and the metrics used to answer the questions described above. Finally, a section of conclusions and recommendations.

II. Social Network Analysis

A social network is a social structure made of individuals (or organizations) called "nodes," which are tied (connected) by one or more specific types of interdependency, such as friendship, kinship, financial exchange, dislike, sexual relationships, or relationships of beliefs, knowledge or prestige[1]. As long as, as mentioned in [5], the social network analysis offers the methodology to analyze social relations; it tells us how to conceptualize social networks and how to analyze them.

The social network analysis (SNA) is an approach used to find information not evident within the structures formed by the interaction between user groups or entities. As you can read in [5] the objective is to detect and interpret patterns, in the social ties between actors that provide additional relevant information about the operation and characteristics of a network of some kind.

Because of its inherent power to reduce a system to its individual components and their relationships (network characterization), moreover the existence of several metrics (sociometric) and indicators that characterize these structures, is an approach that has gained popularity in recent years, successfully applied in scientific and technological disciplines as diverse, mentioned in [13], some examples of projects: conflicts of interest [1], criminal networks [14], search of influential individuals [15], study of co-authors networks [3], among others.

For a few years ago the social network analysis has been used in several initiatives, such as [12], which have selected as a data source the content generated via Web 2.0 tools and have developed networks in order to apply concepts of social network analysis and find a starting point on the road to the Semantic Web, showing that the semantics can emerge from a users communities and through simple actions such as tagging. For the creation of ontologies, the social network analysis has been used on data repositories created by user's communities to find lightweight ontologies, lacking some formalities such as restrictions, but they cover a large number of entities that have been created to through simple actions, but extremely participative.

Within this issue is important to mention the model of ontologies, Actor-Concept-Instance proposed in [12] inspired by social tagging mechanisms, creates semantic-social networks represented in a tripartite graph, person, concepts and instances, expanding the traditional concept of ontology (concepts and instances) with a social dimension.

According to the model, a network of folksonomies is a hypergraph with ternary sides, where each side represents the fact that an actor (user) associated with a certain instance (resource) with certain concepts (tags). From the ternary hypergraph, is posible obtain three bipartite graphs (actors and concepts, concepts and instances, and actors and instances) of whom (actors, concepts) shows an ontology formed by the interests of communities, while (concepts, instances) reflect ontologies formed by the co-occurrence of tags in the resources, thus showing how from a folksonomy can be deduced an ontology.

In SPARQL, arises the need to incorporate, to RDF graphs, some concepts and metrics own of social network analysis, such as: length between nodes, the search for shorter paths, among others, and this way enlarge the information than a SPARQL query provides, as show [7], [1], [14], [8], [2]. With these information extensions, SPARQL will be able to find certain relationships that have been called semantic associations or complex semantic relationships. Semantic associations are meaningful and relevant complex relationships between entities, events and concepts. They lend meaning to information, making it understandable and actionable, and provide new and possibly unexpected insights [14]. Discovery of semantic associations is the process of finding paths of possibly unknown length that connect the given entities and have a specific semantics [8].

1 Taken from Wikipedia http://en.wikipedia.org/wiki/Social_network

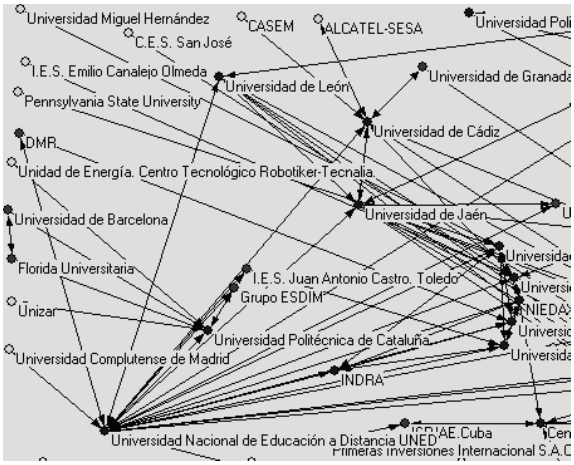

Figure 1. A section of the network constructed

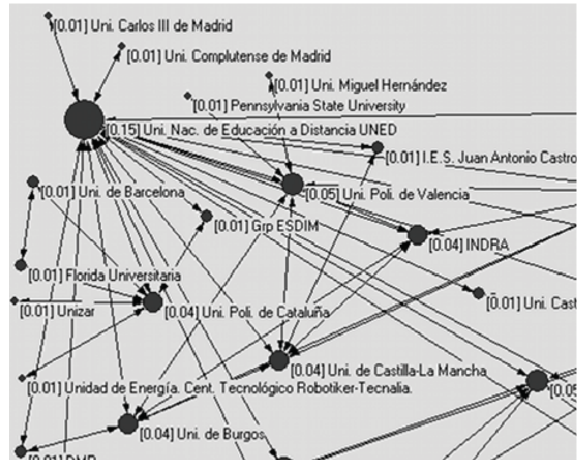

Figure 2. Vertex degree. Each vertex shows your degree

The SPARQL extensions are potentially applicable to: discovery of conflicts of interest, the study of criminal networks, for example.

Other applications of social network analysis, similar to the analysis described in this document can be found in [9], [10], [11] and [13] whom have taken as a data source code repositories of open source projects, including: Apache, GNOME and KDE; building a methodology which highlight the relevant information for a given aspect of project, as mentioned [10].

Another similar application can be found in [6] in this case the data source are communication archives, such as e-mails, blogs, with the aim of improving the understanding of organizational behavior in a company.

In [4] was used social network analysis to detect interesting structures in the resource repository called SIO (Slovenian Educational Network).

III. TAEE Project as data source for the meta-analysis

Under the project of Technologies Applied to the Teaching of Electronics[2] since 1996, a biannual conference has been organized that talks about technologies for teaching electronics and whose aims to disseminate results of projects and initiatives in the areas of educational innovation and application of new technologies in teaching electronics. The presentations prepared for each conferences are varied but have been classified into large families themes such as: Systems, Devices and Components, Instrumentation & Measurement, Automation, Robotics, Laboratories, Educative Software, Teaching and Construction Techniques, Implementation and Practical Realization. The documentation generated by each article in each conference is a source of data to exploit and seize.

2 ¿Qué es el proyecto TAEE?. Proyecto TAEE: Un entorno para desarrollar proyectos. (Disponible en: http://www3.euitt.upm.es/taee/presentacion/presentacion.htm)

For the development of this article we took as a data source, the documents generated in the congress of TAEE Project, 8 congresses executed (from 1996 to 2008) organized in 150 sessions, which has resulted, in a data group consisting of: 964 documents, 1348 unique keywords, 1092 participating agencies, 1674 authors, 9 thematic families, several levels of specialization in each of the families, 4425 learning objects extracted from each article and approximately 5000 references.

The data listed above were provided by the organization of TAEE congresses and were delivered in two formats, spreadsheet and a database of MS Access.

To perform the meta-analysis was used Pajek[3], an open source tool designed for representation of large volumes of data. There are other tools like Pajek, how can see in "Social Network Analysis: Introduction and Resources"[4]

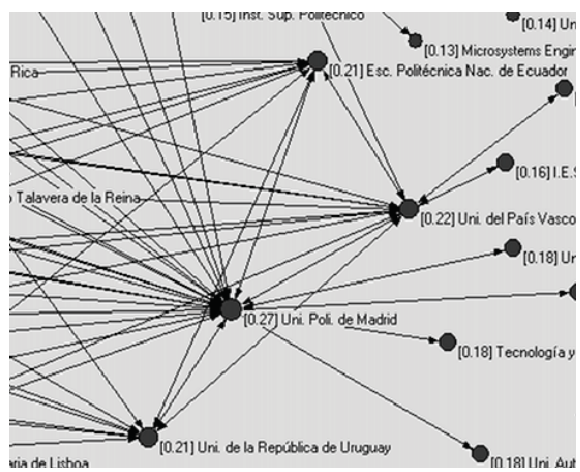

Figure 3. Closeness

3 http://vlado.fmf.uni-lj.si/pub/networks/pajek/

4http://lrs.ed.uiuc.edu/tse-portal/analysis/social-network-analysis/#software

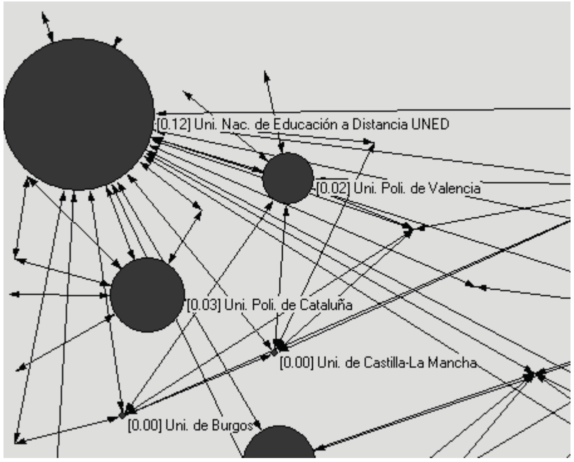

Figure 4. Betweeness

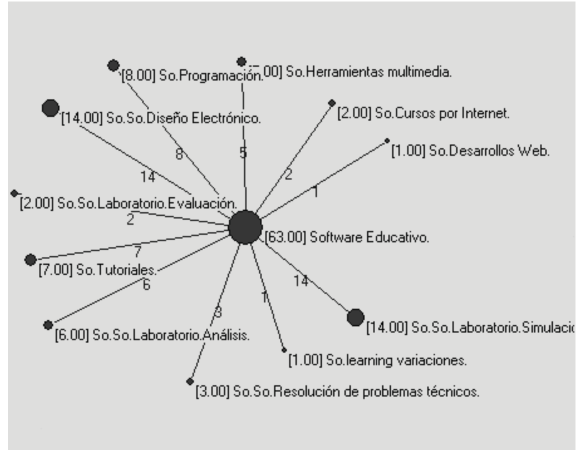

Figure 5. Thematic classification to Educative Software in 1994

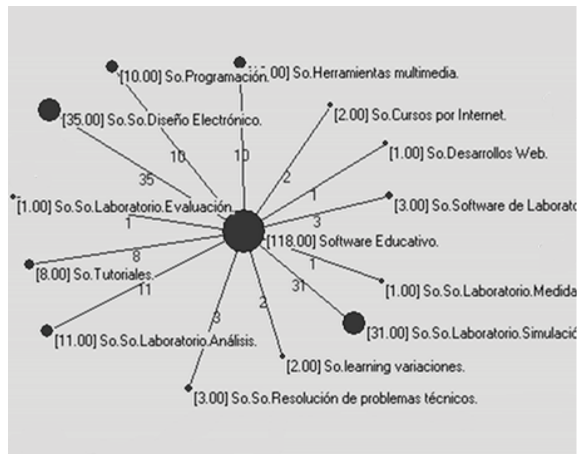

Figure 6. Thematic classification to Educative Software in 1996

Most of the data for meta-analysis were obtained through SQL queries executed against the database and the results were exported as plain text files. In some cases Java programs were developed that allowed to obtain structured data files in the format of Pajek.

IV. Application of social network analysis

Through meta-analysis, we have attempted to answer the questions: What are the relationships and the level of cohesion of the different organizations (at the level of Spain and across continents) involved in TAEE?, How have evolutioned the thematics covered in the conference?, What are the new ontological additions in technology over the years?, and How have evolutioned the thematics in the research and studies related to teaching electronics?

To answer these questions, we have used several metrics of social network analysis, such as vertex degree and density (to study connections and distances between the actors), degree centrality, closeness and betweenness (to determine those organizations with greater power and centrality). Furthermore, we have used Weighted networks, Hubs and Authorities for analysis of thematic and keywords. Lastly K-cores for the study of substructures formed by the relationships between the authors of documents. The results obtained by applying social network analysis on the Congress documents of TAEE project is a complement to statistical analysis, and has permitted: see graphically the relations between the different participants as well as the development of thematic families by facilitating the task of finding isolated organisms and those organisms that serve as a link or bridge with others, and has identified the relationship between keywords in different thematic families.

TABLE I. Summary of the vertex degrees

Degree	Frequency	Representative
0	51	SELCO. SA
2	36	ALCATEL-SESA
4	13	DMR
6	8	AYDE, S.L.
14	6	I.E.S. J.A. de Castro Talavera de la Reina
20	6	Cent. Fed. de Educacao Tecno do Paraná. Brasil
42	1	Universidad Nacional de Educación a Distancia UNED
52	1	Universidad Politécnica de Madrid UPM

A. *What are the relationships and the level of cohesion of the different organizations (at the level of Spain and across continents) involved in TAEE?*

To answer this question was built a network composed as follows: the nodes or actors representing the organizations participating in any edition of the congress. The arcs of the graph are formed between organizations that cooperated in the creation of any presentation, at least once; due to lack of hierarchies, the arcs are bidirectional. See Fig. 1.

The indicators and metrics used to answer the question were: cohesion, density, centrality, vertex degree, closeness, and betweenness. Before to continue is necessary some definitions.

Cohesion is the degree to which actors are connected directly to each other, forming groups, and intuitively means that a social network contains many arcs [5]. To determine the degree of cohesion there are some metrics that are described briefly below:

TABLE II. TABLE SUMMARIZES FOR THE INFORMATION OF THE THEMATIC TEACHING

Teaching	1994	1996	1998	2000	2002	2004	2006	2008	Año
Análisis Si. enseñanza experiencias didácticas	X	X	X	X	X	X	X	X	1994
Aprendizaje basado en tareas	X	X	X		X	X	X	X	1994
Aprendizaje basado en proyectos	X	X	X	X	X	X	X	X	1994
Metodología docente	X	X	X	X	X	X	X	X	1994
Estudios relacionados con educación	X	X	X	X	X	X	X	X	1994
Espacio Europeo Educación Superior						X	X	X	2004
Docencia a distancia		X		X	X	X	X	X	1996
Ap. On line	X	X	X	X	X	X	X	X	1994
Material educativo y docente	X	X	X	X	X	X	X	X	1994
Innovación docente	X			X	X	X	X	X	1994
Aprendizaje basado en prácticas	X	X	X	X	X	X	X	X	1994
Mode									1994
Frequency and median	9	9	8	9	10	11	11	11	M_e = 9.5

- Density: is the proportion of existing ties or arcs in a network with relative to the total number of possible arcs. The density calculated for the network of all organizations that participated in a conference is 0.0191 which means that only 1.91% of all possible arcs are present, although as noted in [5] the density is not a useful measure of their dependence on network size. See Fig. 2.
- Centrality: This measure provides an approximation of the social power of a node on the basis of how well "connected" found on the network. For the calculation of centrality, the following indicators: degree, closeness and betweeness have been used.
    - Degree: The vertex degree is a count of the number of ties or arcs (incoming, outgoing or both) with other actors or nodes in the network, for summary sees Table 1.
    - Closeness: It is the measure that has a node and shows how close is (directly or indirectly) to all other nodes in a network. It reflects the ability to access information through the group of network members. It is inversely proportional to the sum of the shortest distance between all nodes in the network. See Fig. 3.
    - Betweeness: This measure shows how a node is, compared to other network nodes. This measure looks at the connectivity of the neighboring node, assigning a higher value for the nodes that serve as bridges between clusters. The measure reflects the number of nodes that a node connects indirectly through their direct links. See Fig. 4.

TABLE III. THE MOST IMPORTANT ARCS BOTH BY THE WEIGHTED ARCS, AND BY THE AUTHORITIES ANALYSIS

Weighted arcs			Hubs y Authorities		
Order	Keyword	Weigth	Order	Keyword	Weigth
1	instrumentación	174	1	EEES	0.04
2	PCB	192	2	multimedia	0.04
3	multimedia	200	3	laboratorio	0.06
4	docencia	286	4	docencia	0.07
5	laboratorio	315	5	diseño	0.08
6	análisis	326	6	análisis	0.09
7	diseño	367	7	simulación	0.09
8	metodología	409	8	metodología	0.10
9	simulación	420	9	práctica	0.11
10	práctica	550	-	-	-

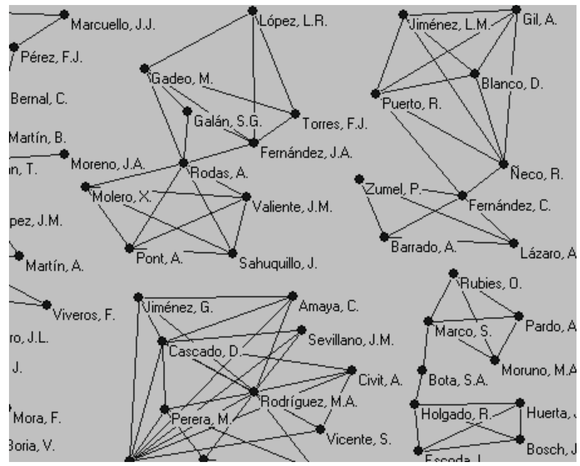

Figure 7. Part of k-cores in the authors network

B. How have evolutioned the thematics covered in the conference?

To answer the question several networks were formed, one by year of publication of the congress, whose nodes are the thematic (which remained fixed in all the years) and their sub-thematic (which appear and disappear depending on the existence of documents classified under this sub-thematic). Giving as result 9 groups, one for each thematic, around which are shown, according to existence of documents, the sub-thematic.

For the arcs, we used weighted arcs, the weight representing the number of documents belonging to a sub-thematic. The diameter of the nodes varies proportionally to the number of documents that were published, it should be noted that the nodes that represent the thematic, show the total amount of documents.

As mentioned above the metric used was the weighted arcs, which is a value assigned to an arc to represent a certain characteristic and the weights can be classified into input, output or both.

In the following figures (Fig. 5. and Fig. 6.) you can see part of the evolution of the Educative Software thematic in the events of the years 1994 and 1996. To the generation of images we used an option of Pajek called "Generate in Time" [16] option that generates a series of images from a single data file.

Through the series of generated images, was possible: classify into groups according to the level of specialization; get the years in which different thematic achieved its minimum and maximum levels of specialization, and find the families whose thematic had a lower index changes.

C. What are the new ontological additions in technology over the years?

To answer this question were selected the following thematic: Systems, Educative Software, Devices and Components, Automation and Robotics, considering them, that are the families more related to the area of technology. In addition, use the metric called the weighted arcs and the statistical measures: mode and median. The mode, allow get the common year in which they appeared each sub-thematic, while the median is used to determine the number of sub-thematic.

The above has helped focus attention on a specific subset and provides numerical arguments that describe the group's situation. Demonstrating that social network analysis needs to be complemented with statistics metrics and vice versa.

D. How have evolutioned the thematics in the research and studies related to teaching electronics?

Like the previous question was used: the weighted arcs, mode and median to answer this question, but the thematic family selected was Teaching. The following table, Table 2 shows a summary of the data source to calculate the mode and median.

E. Another analysis

The following analysis not responds to a specific question, but we use it is to show relevant information about the network behavior of thematic families and keywords, and the network of authors and co-authors of articles.

- Thematic families and keywords. This analysis tries to show the use of keywords in the description of the documents that belong to a thematic family. It formed a network of nodes representing the thematic families and keywords, there is a tie between thematic family and keyword if there are one or more documents that belongs to a thematic family and was described with that keyword. To perform the analysis, the following metrics were used: arcs weighted, Hubs and Authorities, this metrics try to show that a keyword is important not only for the number of times it is used, but instead it is important for the way in which used. Hubs and Authorities are useful metrics for finding important vertices inside a network structure. A node is a good Hub if it points to a number of vertices that are good Authorities, and a node is a good Authority, if it is tied to several vertices, that are good Hubs. The most important arcs both by the weighted arcs, and by the Authorities analysis are: Teaching, Educative Software and Systems, while keywords (Hubs) are summarized in the following table, see Table 3.

In the analysis of Hubs and Authorities, and as shown in Table III, only 9 keywords are showed, because the Pajek did not generate the tenth, possibly due to the lack of a keyword that is used to describe the 3 Authorities. We can see how the ranking of keywords varies depending on the type of analysis, even; we can see the omission or addition of other.

- Authors and co-authors. The objective of this analysis was to show the groups constructed by the authors of published documents, and beyond the simple groups, we can see how simple groups interact to form larger groups. To do this analysis, we formed a network whose nodes are authors and there is an arc between two nodes, if two authors have collaborated to write an article. The metric used was K-cores. A k-core is a maximal sub-network[5] in which each vertex has at least degree k within the sub-network [5]. It uses the degree of a vertex to identify groups (clusters) of vertices that are strongly connected because each vertex has the same level within the group. The value of index k was selected to display as many authors as was possible. Fig. 7. show part of the graph. In the case of the Fig.7. we set the value of k to 4, which means that groups are formed by nodes that are related to 4 nodes, ie the degree of each node is equal to 4.

V. Conclusion

Through the development of this work, we can draw the following conclusions:

- The answers to the questions raised were developed using techniques of social network analysis. Demonstrating that most activities that involve a group of people can be represented through a graph and can apply techniques of social network analysis to characterize them.
- The social network analysis is a type of analysis that allows to obtain other relevant information, complementary to other analysis like statistical and, through the metrics and indicators that it has, is possible to show with numerical data, the different characteristics that a social networking has.
- Through analysis of the relationships between thematic families and keywords, we can see how social network analysis provides a different approach that shows other information in a simple, fast and graphically.
- The meta-analysis just presented in this document has served to provide insight from massive data analysis and statistics. From this point of view has been included joint variables parameterization based social networks and graph theory by using the Pajek tool.
- TAEE congresses have followed a positive development reflecting the electronics world in terms

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A maximal subnertwork is a network with maximum density of thematic diversity and their adaptation to new techniques and products.

- However, the partnership between organizations and between authors from different organizations is a topic that could be improved, in addition to achieving a better balance between organizations from different continents. From this paper, the authors support the dedication of all the organizing committees of various conferences and summons them to encourage to new organizations to participate and strengthen partnerships between organizations.

In order to generalize this type of analysis for any repository generated through user communities, we make the following recommendations, attempting to mitigate some risks described in [12]:

- The ternary hypergraph, could be formed by authors (actors) who write documents (resources) that are described by keywords (tags).
- To achieve the volume of information necessary to ensure the accuracy of the generated ontologies, is necessary the publication of documents on a public website, accessible through the use of Web 2.0 tools that allow the enrichment level of tags, for the resource description.
- To avoid some of the problems in creating the folksonomy, especially to avoid the use of nonstandard acronyms and errors in writing, we propose the use a suggestion service (but not with the intention to limit, restrict or impose criteria to users) without losing the social participation and freedom to choice.

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Social Media Enhanced Studying and Learning in Higher Education

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Abstract—**Social media services have recently become well known especially among young people [1]. In social networking sites a user can participate intensively in activities in the service. To support collaborative study at Tampere University of Technology (*TUT*) and also to provide social networking tools for students especially at the beginning their studies, the development TUT's own social network site was begun in spring 2008. To make the system popular among students, developers and researchers at the Department of Mathematics and Hypermedia Laboratory at TUT designed interventions for fall 2009 when the semester began and new students started their studies. The earlier research [2] revealed numerous motivating aspects that should be somehow included in a study oriented social networking site. This paper will describe the research results of interventions to motivate students to use a social networking site in the context of studies. The results will show that such an environment with social aspects connected to studying and study life on various levels is a means of enhancing studies and basically a necessary tool, especially for students in the early phase of their studies in a new university. The motivation should be further encouraged by the system itself when it relies on students' own voluntary activity. Moreover, the intensive actions of developers, researchers and administrators can be used as tools in directing network activity development.**

Keywords; social media, social networking, study support, motivations, interventions, mathematics

I. Backgrounds

Web 2.0 based social media services (e.g., *Facebook*®[1], *LinkedIn*®[2], *Last.fm*®[3], etc.) have recently become well known especially among young people. There is clearly something appealing in web-based social services [1]. In social networking sites a user can participate intensively in activities in the service, share contents, debate and share opinions and create different kinds of groups for different needs. Why use social networking sites in the study context? Kärkkäinen [3] observed that one of the crucial problems in (Finnish) university level studies is that the very early steps at the beginning of studies are the most difficult for many students. One reason for this is that only a few new students know any of their peers at the beginning of studies in their new university.

To support collaborative study at Tampere University of Technology (*TUT*) and also to provide social networking tools for students especially at the beginning their studies, the development TUT's own social network site was begun in spring 2008. The development project is still running and the site has been improved.

Social network sites are defined as web-based services that allow individuals to (1) construct a public or semi-public profile within a bounded system, (2) articulate a list of other users with whom they share a connection, and (3) view and traverse their list of connections and those made by others within the system [1].

II. TUT Circle

The social networking site *TUT Circle* is a web based environment for students offering customized tools for enhancing social aspects of student life at TUT. The primary target is to provide an efficient and compact system to help new students at TUT to create new social contacts with each other and with students already studying at TUT, e.g., peer tutors etc. The secondary target is to help students form studying groups and circles for their own needs considering their motivations, attitudes, learning methods and orientations [4]. Supporting studies is one part of the whole.

The passivity in the use of the first version of TUT Circle, which was mainly designed to be a tool for collaborative studying at TUT, and the results of the study regarding students' motivation for social media enhanced studying and learning led the developers and researchers to include the context of studying and especially first year mathematics studies at TUT as a different kind of widgets offered to users through specific interventions. The research on students' motivations to use social networking sites in the context of studying showed that systems of this type should not be too complex to use and that the added value for the student should be something unique. A networking site in the context of a student's own university could suffice to motivate students to use the system if it works properly and provides only the tools needed for basic interaction and social activity [5]. Developing a new Facebook was deemed totally worthless [2].

1 http://www.facebook.com/
2 http://www.linkedin.com/
3 http://www.last.fm/

TUT Circle uses an open source CMF (*Content Management Framework*) *Drupal*®[4] that provides basic tools for content management and editing. With specific modules the system can be tailored to various needs. Therefore building up a social networking site on CMF is not a problem in Drupal. Technically development focused on improving the dynamics of the network. In TUT-Circle there is a personal dashboard for every user. The dashboard collects all activity of the user and the user's neighborhood into one page in a systematically ordered way and in real time. Even the activity of users outside the user neighborhood is shown on the dashboard, which enables the user to widen his/her network [2].

TUT Circle is in general a social network site with separate features offering support for studying at TUT at crucial points during the semester. These features are brought into the system through well-planned interventions. The priority is to support new students' social networking process in real life at TUT. Student life at TUT includes a variety of aspects of everyday life. TUT Circle provides a channel for individuals and groups to join together and share the same interests etc.

To make it much clearer that TUT Circle is not primarily a learning environment at all, new students that started their studies at TUT in fall 2009 received information about the system already in summer 2009 before arriving at TUT. This way the new students could familiarize themselves with TUT in general and got to know each other beforehand. This was thought to facilitate the start of studies at university level [2].

As a social network site TUT Circle provides all the common tools for interaction between individual users. Every user has his/her own profile where a wide range of information about user him/her can be shared with others. Typical profile information is e.g., name, gender, date of birth, year of starting studies at TUT and degree program. A user can also add something about his/her hobbies, interests, skills and life in general (e.g., biography, place of birth and current place of residence) [2].

Among basic user actions like status updates and private messaging between users every user can request some other user to be his/her friend in TUT Circle. The friend requests must be accepted before the relationship is formed. Through these friend requests and by accepting others' requests a user's neighborhood in the environment widens and more options for social activity become available. For example, in a user dashboard friends' activity is shown with higher priority. Furthermore, the system can more precisely suggest other users of network as potential friends for a particular user. These suggestions are based on social network theories concerning friend's friends etc. Simple SNA (*Social Network Analysis*) [6, 7, 8] methods and algorithms are used to find potential users.

To enhance the dynamics of activity all content in TUT Circle can be tagged with keywords. These tags help users to find contents on particular topics dynamically without using complex searches etc. Tags also support social networking when users can easily list all users e.g., according to some specific interest or hobby. Tags describing geographical information such as place of residence and place of birth can be shown for all users or restricted to user's neighborhood using *Google Maps*™[5] based map widget [2].

Groups in TUT Circle provide more efficient tools for collaborative activity in the environment. Every user can create his/hers own group. The purpose of the group is not restricted and topic can be anything that is relevant. Every group has member management tools and the visibility of a group in TUT Circle can also be modified by a group administrator (the creator of the group). A group has tools to help collaborative activity and even group studying and learning in web environments. In a group members can chat, write news, manage events, write blog posts and edit wiki pages collaboratively. Sharing resources (e.g., files, images, etc.) is also an option [2].

The discussion board has a static structure that helps users to find the correct forum for their posts more easily than in discussion boards with user modifiable tree structure of discussion topics. Under every default topic users can initiate new discussions about subtopics related to the primary topic and these subtopic trees are user modified. The default topics consider many aspects of student life at TUT. One topic is discussion about first-year studies; another is student life in general. Topics related to leisure time and living in Tampere are also included, likewise a flea market where students can easily sell and buy items (e.g., course books, furniture, etc.) from each other [2].

The questions feature enables every user to ask a question anonymously. This feature was developed because according to the research students found it easier to ask even a stupid question out loud if it was possible to do so anonymously. Every user can answer these questions and the answers are given with a name. This gives active respondents social credit when they help others with their responses. It also gives visibility for a respondent when his/her answer to a question is shown on dashboards [2].

Furthermore, the questions feature is used to support studies in Basic Engineering Mathematics. Through an intervention special groups in the context of mathematics are brought into the system and users are directed to join them. In these groups users studying mathematics at TUT can ask questions about mathematics anonymously and an online tutor answers those questions. Clearly every user can also answer any question. This way lecturers teaching Basic Engineering Mathematics can recommend the TUT Circle for students as a system for supporting studies and truly rely on the fact that support really can be obtained [2].

Other features designed to support study are mainly special widgets available to users through interventions. These widgets are surveys etc. One example is a *Mathematics Horoscope* which through a 15-question survey tells the user how he/she is oriented to study mathematics, his/her mathematical skill level and how he/she could study mathematics at TUT to learn certain topics better. Students also get some tips on how to improve their study methods [9]. The analysis of the survey is based on a study conducted at TUT on students' skills, orientations and methods in learning mathematics [4].

III. MOTIVATIONS TO USE WEB COMMUNITIES IN STYDYING

According to McMillan and Chavis [10], there are a four features of sense of community; (1) feelings of membership

[4] http://drupal.org/
[5] http://maps.google.com/

(i.e., a member has a feeling of belonging to, and identifying with the group), (2) feelings of influence (i.e., a member has feelings of having influence on and being influenced by the community that emerge from enforcing and challenging norms within the group), (3) feelings of reinforcement of needs (i.e., a member feels support from others, has status in the group, and meets other people's needs while having his/her own needs met) and (4) feelings of shared emotional connection (i.e., members feel having a relationship and a shared connection with others due to frequent and high quality interaction) [10].

In the earlier research [2] it was noticed that the nature and purposes of a social networking site affect users' motivations to use the systems. Simple and easy might even be considered lame, but on the other hand an excessively complex service might overload users' capabilities in system usage [11]. Furthermore, it has been observed that in addition to exemplifying principles of usability and accessibility, the system should be visually fascinating and technically modern and workable (see Table I) [2]. The connection between the service and the context should be obvious, i.e. student life related activities and topics should be easy to bring into the service. "Using the service it's easy to find other students in the same phase of studies. This will help a student to take studies more personally, when the networking service gives a user a sense of belonging", one student earlier encapsulated the general mood in his answer. Another student claimed: "When users' first experiences of system usage were positive the information about the system started to spread to other students, for example, in coffee table discussions." After all, the quality of a social networking site depends on the quality of the community within it [2].

Students are not so interested in joining a networking service that lacks users to be connected with, but it was noticed during TUT Circle first version usage that an empty networking service does not gain any content. For example, according to Nielsen, [12] most users (90 %) are lurkers who just read messages and only 9 % produce contents once in a while. Only 1 % of users can be considered to produce contents constantly. Despite these limitations the sense of belonging to the student web community is deemed important: "For many youngsters starting their studies at university might be somewhat difficult, because older peers often start their studies somewhere else or stay in their home town. Especially if the high school and the university are in different towns it is inevitable that old friendships get weaker and new friendships are formed with other university students. Sometimes it is hard to get to know new friends out of the blue. It usually takes days, often weeks. Studying generally feels better, when one does not have to study alone… In the web it is easy and comfortable to meet new people and discuss with them. Starting a discussion and joining one is often easier in the web than face to face. In a social networking site in the context of university studies one can seek and find new and old students from a specific study program and get to know them already before actual start of studies as well as during the studies. This could be a convenient ice breaker for many students. Discussion face to face could be easier at the first meeting, when both could recognize one another."[6]

[6] A quote from a student's answer in the research data

TABLE I. ASPECTS INCREASING AND DECREASING STUDENTS' MOTIVATION FOR STUDY ORIENTATED SOCIAL NETWORK SITE USAGE [2].

	Motivating	Non-motivating
Background and reputation of system	Voluntariness Free of charge Positive usage experiences General popularity Trendy Fashion craze	Narrow focus Bad or dubious reputation Unknown system Uninspiring
Basic idea and targets	Centralization of information Collaboration Social networking Improvement of communication Connecting studying and leisure	Nothing new Everything about anything in one place Similarity to other services available
Usage needs	Networking Social interaction Enriched user profile University related information sharing Study support Connecting users with similar interests etc.	Irrelevant features The system is not supported to be adjusted to individual user behavior Lack of interactivity
Functionalities	User-to-user relations Messaging Groups Discussions Resource sharing Managing events (incl. calendar) Collaborative content production	Complex widgets Irrelevant games
Content	Information about student life University related content General discussion board with clear structure and relevant topics (e.g., living, studying, jobs, buy or sell, …) Study schedules	Lack of content Too much information Irrelevant or too specific discussion topics (e.g., discussion about one single course etc.) Spam messages
Usability	Easy to use Clear and simplified user interface	Too complex structure Content cannot be found easily Long chains of navigation
Layout	Eye-catching layout Trendy theme	Machine-like Lack of pictures and images
Technical sustainability and flexibility	Fast and stable system Fault tolerance Fully functional Open interfaces User agent independence	User feels like a test user Unstable system Parallel systems cannot be synchronized Lack of mobile version
Moderation	Continuous surveillance and development Bug fixing Responses to feedback Short service breaks (prior notice sent to users)	Slow and/or inaccessible administrator Lack of surveillance No control Long service breaks Feedback is ignored

Figure 1. TUT Circle profile page with RSS feed from *Audioscrobbler*[7] (Last.fm) and *Twitter*™[8].

IV. Research Data and Data Analysis

To make TUT Circle popular among students, developers and researchers at the Department of Mathematics and Hypermedia Laboratory at TUT designed interventions for fall 2009 when the semester began and new students started their studies. During summer 2009 the focus was on encouraging the activity of new students so that in fall the study supportive widgets would have been easily-obtained and used by students. Furthermore, the activity was monitored and the development of networks in TUT Circle studied using social network analysis methods and applications.

In autumn 2009 data was also collected from 38 hypermedia students regarded as early adopters. They were asked to sign up for TUT Circle and analyze aspects, functions, or features motivating users to use the service. In this evaluation students used a specific *WeSQu* tool and its User Motivation section. WeSQu is a web-based tool for evaluating web service quality, e.g., in terms of reliability, accessibility, visual design and community properties [13, 14, 15].

WeSQu's theory is based on research in HCI (human-computer interaction), psychology, and pedagogy as well as on evaluation research, which has its roots in the theory of usefulness of computer systems. The usefulness of web-based services includes usability and utility sections. The framework is needed to define the factors crucial to the implementation of web services for a varied group of users. The main issues within this evaluation framework are usability, added value as well as accessibility and informational quality of web services [16, 14, 17, 18].

Usability means that the user interface of a web-based application must be easy and effective to use so that the user can concentrate on the information content instead of the interface. When software is usable it is easy and efficient to use, easy to remember, has few errors and it is subjectively pleasing [18].The added value of web services can be evaluated as in conventional services. Is there something special or something new for users? An essential part of quality is also accessibility, because web design today is designed for individuals in various contexts with different devices [19, 20]. The fourth part of quality is the informational quality of any web service. To be of high quality the informational content of a web service should meet the five main criteria: accuracy, authority, objectivity, currency and coverage [21, 22, 23].

In addition the foregoing quality experiences of web services are also subjective and depend on the user's personality, expertise, needs and use situation and context [24, 25]. WeSQu's User Motivation section concentrates on means of awarding the user for using the system, how different user groups are considered, how the system can be personalized and how easily service content can be followed. In addition, the students were asked to analyze the extent of evaluation.

The total amount of text data collected was 160 pages. The data was analyzed using theme analysis, which is suitable for research pursuing more profound knowledge about a phenomenon and having theory based data collected. In practice theme analysis is data slicing and rearrangement in different categories. The purpose is to find themes explaining the research problem, i.e. relevant topics are identified and separated from text data. A strict connection between data and theory is crucial in theme analysis [26].

V. Results

In the evaluations the same topics from the earlier research (see Table I) were emphasized. In addition, the following was highlighted in students' answers:

- New features should be added into the networking service a bit by bit. It was considered that beginning system usage is easier if a platform is fairly simple at first. To maintain interest there was appreciation for new functionalities introduced in the platform, when the network was organized and properly formed.
- A networking site is a suitable tool for promoting different events for students. The option to add geographic information [27] into the Google Maps widget [2] was deemed very motivating: "…Profile section is fairly versatile and it is very easy to add information, e.g. a map with a tag representing one's own home or home town."[9]
- A profile level indicator was considered a good feature. It was also appreciated that a user can give only the personal information he/she wants to share: "Different kind of interests are also clearly visible if wanted. This helps to find similar or certain new friends and can also enhance the motivation to use the service when one can show what kind of music and movies he/she likes. It is also convenient that titles of songs listened in Last.fm (see Fig. 1) can be imported to TUT Circle."[10]
- It was motivating to follow friends' events, content and profile information.

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[7] http://www.audioscrobbler.net/
[8] http://twitter.com/

[9-10] A quote from a student's answer in the research data

- E-mail messages about new features and content feeds are increasing the participation in content producing in the social networking site. In addition, content feeds in a user dashboard were considered to be motivating: "The dashboard gives a great overview of all new content and activities."[11]
- A function to register like or dislike of content and features was desired, likewise listings of the most popular content, users, actions, etc.: "…The 'like' function gives a user an opportunity to give positive feedback on content produced by another user."[12]
- RSS feeds were considered convenient functionalities: "A chance to export an RSS feed from a discussion board also motivates users, likewise the option to produce one's own content."[13]
- Some students emphasized the importance of anonymity in web community activity.

After all, TUT Circle was seen to increase a sense of belonging, because in the system it is "easy to discuss local issues and get to know the people at TUT" [14]. Wellman [28] refers to this phenomenon as "glocalization"; the ability of the Internet to both expand user's social contacts and bind them more closely to the place where they live.

For basic usage monitoring in TUT Circle *Google Analytics*™[15] is also used. Using this data the network activity can be analyzed from the perspective of interventions executed. The results of this analysis support the results of motivation research. It is obvious that a social networking site in the context of studying requires constant steering when system usage is not mandatory at any level. Proper interventions can be seen as means to accomplish such network steering, but even successful interventions are not enough alone to maintain system usage at a satisfactory level.

As can be seen in Fig. 2 the usage level can be enhanced by interventions. Obviously, an intervention should be appropriate to users and to the system itself to be successful. It is fairly easy to implement successful interventions of any kind to increase activity in the system for a short period of time,

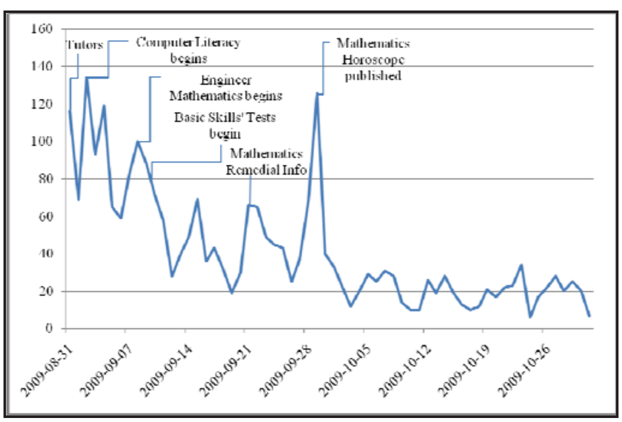
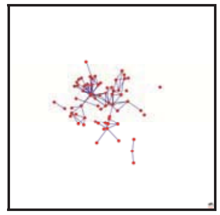
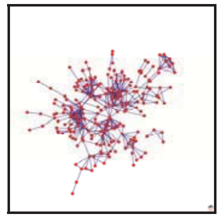


Figure 2. Daily visitors in TUT Circle. The most of the peaks can be explained by interventions executed.



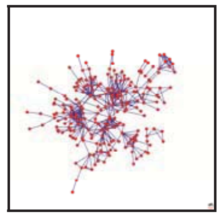
2009-08-31

Nodes: 67
Edges: 101
Density: 0.0457
Degree centrality ∈ [0,0.2273]
Degree centrality variance: 0.0018
Group degree centralization: 0.1872



2009-09-30

Nodes: 213
Edges: 480
Density: 0.0213
Degree centrality ∈ [0,0.1038]
Degree centrality variance: 0.00042
Group degree centralization: 0.0833



2009-10-31

Nodes: 225
Edges: 516
Density: 0.0205
Degree centrality ∈ [0.0045,0.0982]
Degree centrality variance: 0.00039
Group degree centralization: 0.0784

Figure 3. SNA graphs and figures of the evolution of a social network in TUT Circle. It can be seen that the most intensive network evolution occurred in September 2009. However, while the network gained more users its density was declined as well as its group degree centralization. This is explained by several network cliques. There is only few users interacting with many other users in the web based student community.

but successful interventions steering system usage to be more self-oriented are much more difficult to design and execute.

At the beginning of the semester the peer tutors gave the first information and true examples of TUT Circle usage as well as demonstrations on Computer Literacy and Engineer Mathematics courses. Due to this promotion most of the new users were registered in the system and actually more or less started to use the service. However, the sustainability of system usage level was rather sensitive to changes. For example, when new contents did not appear usage was slight. On the other hand, when a new intervention was executed, the usage level soared, for instance, with Mathematics Horoscope by over 150 percent compared to the average usage level of the preceding usage period. However, the interventions did not ensure long-term system usage.

In TUT Circle there is a tool that is used to collect log data in XML (*Extensible Markup Language*) format about different network actions. The data can be used for SNA that enables enriched network information production. Based on log data and together with SNA methods different visualizations can be produced. Visualizations can be used to support the analysis of social networks e.g. to detect changes and weak signals, to gain an overall view of the social network as a whole, and to concretize development of the network [29].

[11-14] A quote from a student's answer in the research data

[15] http://www.google.com/analytics/

TABLE II. PROPORTIONS OF MOST POPULAR PAGES OF ALL DAILY PAGE VIEWS IN TUT CIRCLE DURING THE MATHEMATICS HOROSCOPE INTERVENTION.

2009	User Dash-board	User List	Discus-sion Forum	Quest-ions	Own Profile	Mathematics Horoscope	
						Survey	*Results*
09-28	11.2 %	4.3 %	4.6 %	2.1 %	3.7 %	0.0 %	0.0 %
09-29	13.6 %	3.8 %	2.7 %	1.8 %	2.2 %	4.9 %	4.2 %
09-30	16.5 %	3.4 %	3.1 %	3.1 %	2.8 %	5.0 %	5.0 %
10-01	19.5 %	3.5 %	2.0 %	3.5 %	2.5 %	5.0 %	4.0 %
10-02	14.8 %	3.8 %	3.3 %	1.1 %	1.6 %	1.1 %	0.5 %

SNA was used to analyze network evolution during the intervention process. Analysis was concentrated on friendships formed in TUT Circle. Basically, a friendship between two users is formed through a request-acceptance process. These connections are considered undirected. Moreover, connections are considered dichotomous so that no value was added to describe a connection as intense etc., because analyzed log data included only information about friend requests and accepted or ignored requests.

Through SNA analysis it was possible to create a time series of visualizations representing a network of active users in TUT Circle. The graphs were created using *Pajek*[16] software and its *Kamada-Kawai graph layout algorithm*. Furthermore, detailed information about network was evaluated through SNA analysis using *Matlab*®[17] software.

In SNA graphs network actors are represented as nodes and connections between actors as edges. Characteristic network figures like density and group degree centralization give more detailed information about a network under study.

Network density simply describes how many connections (edges) there are in the network. It gets its maximum value 1 when every possible edge exists in the network. When there are no edges in the network the density is 0. Degree centrality is a proportion of an actor's existing connections of all connections which can be formed with other network actors and thus gets its maximum value 1 when a given actor is connected to every other actor and minimum 0 when the actor has no connections. Network degree centralization describes the rate of a single actor's effect on other actors' interactions on the general level of the network under study. This indicator is assigned a value from 0 to 1 and the higher the centralization index the more interactions there are in the network [6, 7, 8].

A closer view of Fig. 2 connected to SNA visualizations (see Fig. 3) shows that the interventions done did indeed accelerate TUT Circle usage but did not significantly increase the level of social networking in the system. Moreover, it can be seen that the effect of the interventions on general activity in terms of content production and interaction between users was not significant, even though users did return to the system due some certain intervention. In fact, SNA figures such as network density and group centralization indices show that new registered users behaved in the community like all the other users. The network did not become more connected when new users were introduced into the system. Most of the users were connected with their friends, but the interventions did not significantly influence new friendship creation. Basically users only participated in activity related to the intervention and ignored other features offered by the system.

An example of this kind of behavior is an intervention considering the publication of a new feature in TUT Circle. Fig. 2 presents the frequency of daily visitors and the frequency of Mathematics Horoscopes, created daily. The Mathematics Horoscope is a questionnaire that profiles a user's mathematical competencies, study methods and targets with 15 questions. Clearly this new widget motivated users to return to the environment and use the new feature. An e-mail announcement on Tuesday 29th September 2009 activated the TUT Circle users instantly and the effect on system usage level was truly significant. But users were not active regarding anything else in the environment. This can be seen in Table II. Usage of any other function did not increase. Moreover, when the users had once created their Mathematics Horoscope this feature was simply forgotten.

VI. CONCLUSIONS

Crucial properties of web communities are functionalities supporting networking, community evolution and activity [1]. Services are offering various means supporting community members to connect each other and communicate, for example, private and public messaging, commenting, updating statuses, feeds of new contents, popularity listings and different user search options. A challenge for a new web community is still motivating to content provision and production. Although there is a need for a community, only a part of registered users really start to use the networking service. Creating friendships, friend lists and filling in one's own profile interest most users, but actual discussion is still at a low level. Is it actually enough for students to have this kind of tool only to get to know each other, or are there still some other expectations for network activity? In addition, in designing web community functionalities consensus between user privacy and showing interesting content should be found.

Different actors feel their identity in a web community in different ways. It is essential in interactions between individuals that enough personal information can be received so that identification is possible in the community. In contrast to face to face situations, where people are physically present, user identification in web communities is based on information profile information provided by the user him/herself. In profile information a user describes him/herself and on the basis of this information other users are able to identify the user and imagine what is he/she like. There are still some users preferring to act anonymously so that their physical identity is not revealed [1, 30].

Clearly interventions can be used to enhance network activity. A well-designed intervention can increase the usage level significantly, but the long-term effects to motivate students to use a social networking system in the context of studying requires obvious added values for users to be reached through the intervention process. This means that the intervention itself does not feed motivation, but it certainly can activate users.

[16] Pajek is a Microsoft® Windows® based SNA software that is free for non-commercial use, http://pajek.imfm.si/doku.php

[17] Matlab® is a high-level language and interactive environment that enables performing computationally intensive tasks, The MathWorks™ Inc., http://www.mathworks.com/products/matlab/

Connecting the activity in real life and the activity in the social networking site should be seen as adjacent. When something crucial and relevant happens in the real world, some aspects of it could also be processed in the web community. This is still an automated process in only few areas of student life and studying in general. Therefore, an intervention can be used as a steering method that directs students to take advantage of the opportunities provided by a social networking site.

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Three Online Neutron Beam Experiments Based on the iLab Shared Architecture

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Abstract - **Students at MIT have traditionally executed certain experiments in the containment building of the MIT nuclear reactor as part of courses in Nuclear Engineering and the third year laboratory course for Physics majors. A joint team of faculty and research staff from the MIT Nuclear Reactor Laboratory (MIT-NRL) and MIT's Center for Educational Computing Initiatives have implemented online versions of three classic experiments; (a) a determination of MIT reactor coolant temperature through measurement of thermal neutron velocity, (b) a demonstration of the DeBroglie relationship of the kinetic energy and momentum of thermal neutrons and study of Bragg diffraction through a single copper crystal at various orientations, and (c) a measurement of beam depletion using a variety of shielding filters. These online experiments were implemented using the LabVIEW® virtual instrumentation package and the interactive version of the iLab Shared Architecture (ISA). Initial assessment of the online experiments indicates that they achieve comparable educational outcomes to traditional versions of the labs executed in the reactor containment building.**

Keywords - remote Labs, online labs, iLab architecture, web services, engineering education, nuclear physics.

I. BACKGROUND

Online laboratories (iLabs) are experimental facilities that can be accessed through the Internet, allowing students and researchers to carry out experiments from anywhere at any time. They harness the Internet and enable students to access and utilize real instruments remotely. These types of remote labs enrich science and engineering education by vastly increasing the scope and variety of experiments that students are able to access. Experiments allow a student to compare reality with simulations, collaborate with each other, and follow their curiosity. Conducting experiments motivates students and causes them to learn more effectively.

However, many science and engineering classes do not include a traditional lab component due to the prohibitive expense involved in staffing and operating labs, space and logistical requirements and safety considerations. By providing online access to remote laboratories, iLabs are delivering the educational benefits of hands-on experimentation over the Internet to our own students and to students around the world. Remote laboratories allow for the more efficient use of laboratory equipment and can give students access to exciting and unique resources. In this case, the Spectrometer iLab project's goal is to provide educational opportunities to students at various educational levels nationwide and internationally that do not have the benefit of an on-site nuclear reactor or other neutron source.

II. THE ILAB SHARED ARCHITECTURE

The iLab Project at MIT has focused on the design of a common architecture for the development and deployment of online laboratories called the iLab Shared Architecture (ISA) [1]. ISA is a robust, scalable, open-source infrastructure built on web services that provide a unifying software framework to support access to a wide variety of online laboratories. The ISA provides a set of generic lab services, such as user account management, scheduling and data storage, in a middleware system that can be accessed using web services. Students and the online laboratories can be globally distributed across an arbitrary number of locations linked only by the Internet. Users access these remote laboratories through single sign-on and a simple standard administrative interface.

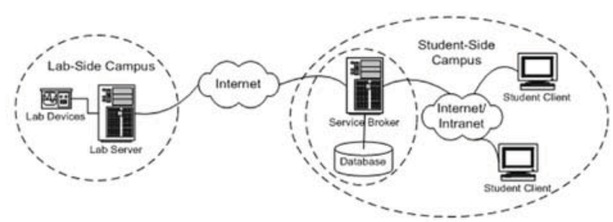

Figure 1. ISA components: Service Broker, Lab Server and Lab Client

A founding principle on which iLabs is built is the separation of responsibility. iLabs separate the responsibility for lab development from that of managing information about the students using the lab. Not only do the services provided by the iLab Service Broker (authentication, authorization, experiment storage, user management) simplify the task of implementing a particular experiment, but the location of the iLab services on a separate server divorces management of students on the Service Broker from management of the lab experiment on the lab server. In a typical configuration, as shown in Figure 1, a campus using iLab-based experiments will run a Service Broker administered by IT staff responsive to their own faculty and students. This Service Broker can access multiple lab servers potentially located at multiple remote campuses anywhere on the Internet. The students' accounts and their experiment storage reside on their local campus Service Broker regardless of where the experiment itself is executed. The lab server team need not be aware of which student is using their equipment at any given time, but they are assured that the student comes from an approved campus. The separation of responsibilities gives iLabs unique scaling properties and potentially enormous economic advantages with revolutionary impact in science and engineering education at all levels.

The iLab Shared Architecture is divided into three major components; Service Broker and related service, Lab Server and Lab Client [2].

The Service Broker serves as the heart of the ISA. It provides generic administrative services, such as authentication, authorization, user management, scheduling and data storage. The design of the Service Broker strictly separates the task of publishing an iLab from that of managing the students using it. This separation encourages the sharing of such experiments between institutions. The Service Broker also serves as the gateway in inter-institutional relationships. Once two institutions have mutually registered their Service Brokers with each other it becomes much easier to share iLabs.

The Lab Server is the component connected directly to the lab equipment and deals with the actual operation of the experiment hardware. It is the administrative interface to the lab equipment and enables labratory administrators to setup and configure each experiment independently. Each lab server is specific to its experiment hardware, and as such, a different lab server must be used for each set of lab instrumentation.

The generic components of the iLab Shared Architecture require communication to be via web services. But the architecture leaves decisions regarding the construction of the experiment to the domain expert and lab developer. This allows developers to use custom, even proprietary, technology both for constructing their lab client and lab server and for managing the experiment based communication between them. Not only does this provide support for specific, potentially high-bandwidth lab experiments, but it also enables support for pre-existing lab control software. In the case of the Spectrometer iLab, we use the National Instruments LabVIEW® platform for both the lab hardware control and the lab client interface.

The Spectrometer experiment utilizes the MIT iLab project's open source reference implementation of the Lab Server called the LabVIEW® Integrated Interactive Lab Server (LVILS). The LVILS provides a standard way for interactive lab developers to interface the generic ISA services to LabVIEW® instrument control software. In the LVILS, as in the interactive model generally, the lab client is developed in close relation with the lab server and corresponding instrumentation. The LVILS furnishes support for accessing the ISA services such as experiment storage and scheduling, as well as interfacing to LabVIEW® Virtual Instruments.

The Lab Client is the interface through which students access the iLab. It provides an intuitive representation of the iLab being run, allowing users to specify parameters and interact with the lab hardware. The ISA supports many client technologies including Java applets, Java Server pages, Windows Forms clients, and LabVIEW® remote front panels.

The ISA supports multiple Lab Clients that utilize the same backend Lab Server and experiment hardware. Building educationally valuable online labs is expensive and it is necessary to leverage, where ever possible, this investment by encouraging the sharing of lab resources. One way to share labs is to develop new educationally appropriate interfaces targeted to specific audiences. The ISA offers a scalable solution to improving STEM education by growing the use of online labs to increase inquiry-based learning and encouraging student interest in science through experimentation. We hope to bridge the traditional gap between the university, secondary school and other communities while recognizing differences in educational context and goals.

Consider, for example, the manipulations required to perform a basic time-of-flight (TOF) spectroscopy experiment. With the chopper wheel motor running, the low efficiency BF3 detector is positioned close to the chopper wheel and data is accumulated using a multi-channel scaler (MSC) card. The detector must then be re-positioned much further from the chopper and the data acquisition process repeated. For this experiment, we plan to develop at least three different interfaces each targeted at a different educational audience.

We envision a variety of client implementations to accommodate the needs of different educational audiences. For high school students, we need a simpler client that is focused on a single experiment which includes a set of predefined detector positions and some initial setting of the counting parameters. This will allow high school students to step through the experiment and observe accumulation of real data with little possibility of experimental errors that might interfere with basic data analysis and understanding.

For advanced undergraduate or graduate students, there is our current client, where students have access to all three experiments and they select the experiment at run time. In this interface users are allowed to determine detector positions for themselves, check and adjust alignment of the detector with the beam and set various MCS parameters.

One could also imagine additional hardware being added to the experiment implementation for research purposes and new clients being developed specifically for research staff. Each of the clients described would use some if not all of the hardware features currently implemented in the Spectrometer iLab but would be geared towards a specific group or classes need.

The iLab team is currently developing a simpler version of the beam depletion or neutron absorption experiment for use in advanced secondary school courses in cooperation with the University of Queensland, Australia and the Queensland Academy for Science, Math, and Technology (QUASMT). We plan to begin beta testing this summer.

III. THE SPECTROMETER EXPERIMENTS

In the early 1980s, Nobel Prize winning physicist Clifford Shull collaborated with the MIT Nuclear Reactor Laboratory (MIT-NRL) to build the neutron spectrometer facility so that MIT undergraduates could replicate basic neutron science and physics experiments. These experiments utilize a beam port which provides a continuous beam of well-thermalized neutrons from the heavy water reflector region of MIT's 5MW research reactor. The experiments are part of courses in Nuclear Engineering and the third year laboratory course for Physics majors [3]. The experiments developed include:

- Measurement of the Maxwell Boltzmann Distribution of Thermal Neutrons. The objective of this experiment (also called the Time-of-Flight Neutron Physics experiment) is to measure the energy spectrum of the beam neutrons using time-of-flight techniques, and then to compare the results with the expected Maxwell Boltzmann distribution that is predicted. Students are asked to perform measurements at two points in the beam guide tube using neutron detectors, multichannel scalers, and oscilloscopes. Students plot the data they gather and attempt to calculate thermal neutron velocity and flux density.
- Demonstration of the DeBroglie relationship of the kinetic energy and momentum of thermal neutrons and demonstration of Bragg Diffraction. The objective of this experiment is to demonstrate neutron diffraction using a copper single crystal. Students are asked to measure the Bragg-diffracted beam that results when the neutron beam interacts with the crystal. They perform several measurements at various angles of incidence, and are asked to plot their data to demonstrate the DeBroglie relation.
- Demonstration of Beam Depletion or Shielding Effectiveness in a Neutron Beam. The objective of this experiment is to demonstrate thermal neutron behavior in the presence of various absorption materials. After characterizing the "open" beam in the TOF experiment, the students place samples of materials such as lead, cadmium, water and borated polyethylene in the beam and repeat their energy spectrum measurement. Based on the data collected, students are asked to calculate cross-section or attenuation coefficient of the materials and qualitatively evaluate how these parameters depend on neutron energy.

The neutron spectrometer was initially designed as a non-automated facility installed in the Massachusetts Institute of Technology Research Reactor (MITR) which utilized the 4DH1 beam port. Students entering the reactor containment building to utilize one of the experiments are required to complete General Employee Radiological Training (GERT) and become radiation workers by federal law. These requirements and other security issues have limited the number of students able to utilize the spectrometer experiments. In 2007, with funding from the Department of Energy's Innovations in Nuclear Infrastructure Education grant for the New England Consortium and funds from the MIT iCampus project, a joint team of faculty and research staff from the MIT Nuclear Reactor Laboratory (MITNRL) [4] and MIT's Center for Educational Computing Initiatives [5] was created to enable online access and usage of these experiments based on the iLab Shared Architecture. Figure 2 shows a rendering of the principal components involved with these experiments. They include a mechanical chopper, a low efficiency detector, a crystal, a high efficiency detector and a materials attenuation slide.

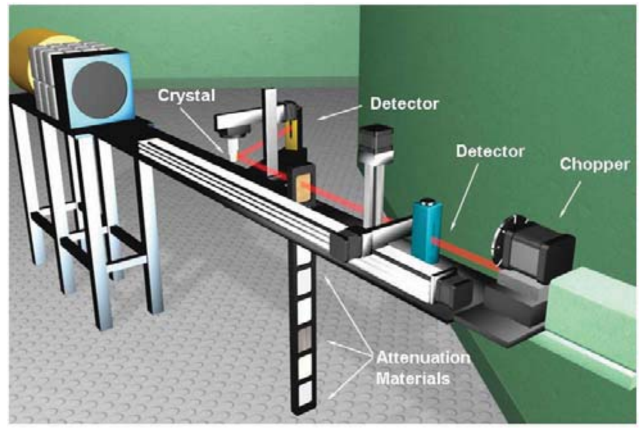

Figure 2. Rendering of the principal components of the spectrometer experiments by R. Mark Bessette (MIT).

IV. IMPLEMENTATION

The student spectrometer hardware implementation can be described in terms of three major subsystems. The first of these consists of the equipment required to manipulate and detect a low energy neutron beam from the MITR research reactor and is essentially unchanged from the established version of the experiment that has been run locally by MIT undergraduate and graduate students for several decades. The main components are a collimator and chopper wheel that produce a narrow, pulsed, beam of neutrons, a low-efficiency BF3 detector (LND Model 201) that is used to count the neutrons in the direct beam, a copper single crystal to diffract the neutrons and a high efficiency 3He detector (LND Model 251) that is used to count the neutrons in the diffracted beam. The detectors are powered by a dual high voltage power supply (Canberra Model 3125) and the signal from each detector is processed by a preamplifier and amplifier/timing single channel analyzer (TSCA) (Canberra Model 2006 and Ortec 590, respectively). These components are mounted in a standard nuclear instrumentation module (NIM) bin. The TSCA produces a sharp voltage pulse corresponding to each detected neutron that is processed by a multi-channel scaler (MCS) board (Ortec MCS-pci™) installed in the local PC. The MCS is gated by a signal produced by a light sensor that detects the passing chopper wheel slits. Accumulating data in the MCS produces a time of flight (TOF) spectrum of the neutrons in the beam that can be converted to an energy spectrum for analysis of the neutron energy distribution.

The second subsystem consists of components used to position the detectors and other elements of the experimental apparatus such as the single crystal and a set of materials that can be positioned in the beam to measure their neutron attenuation properties. Most of the detector motions are accomplished using stepper motors (Automation Direct, various models) with linear slides or rotary tables (Velmex, Inc., various models).

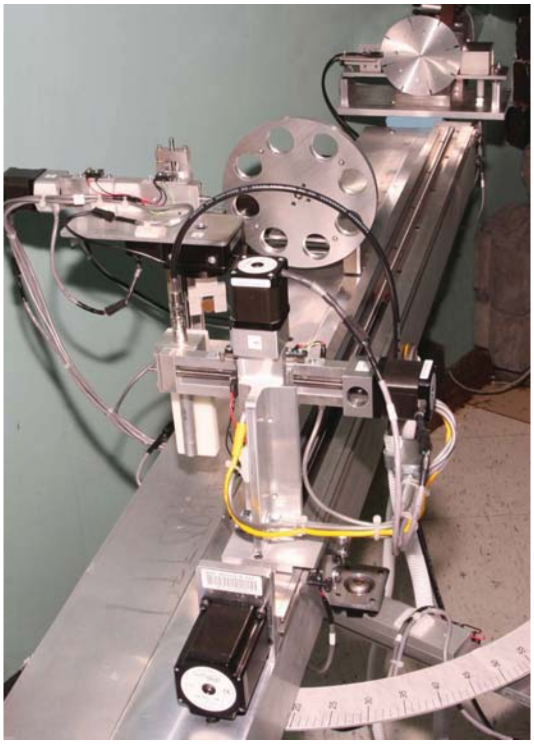

Figure 3. Spectrometer Experiment Hardware

The low efficiency detector has three linear axes of motion: two orthogonal axes perpendicular to the beam and one axis in the beam direction to allow spectra to be generated at varying distances from the chopper wheel. The single crystal has two linear axes of motion for positioning in the beam and one rotational axis to align the crystal planes at varying angles to the neutron beam. The high efficiency detector has one axis of motion driven by a linear slide but producing a rotation centered on the crystal position in the beam. This motion is used to find diffracted neutron beams. A stepper-motor-driven rotary table is also used to select different materials for attenuation experiments. In addition to the stepper motor systems, there are relay-controlled pneumatic actuators to move the attenuation material setup in and out of the beam and to raise and lower the chopper wheel to allow a "white" (unchopped) beam to be produced. A relay is also provided to start and stop the chopper wheel motor. Figure 3 shows the finished experiment implementation of the main components.

The third subsystem is a National Instruments PXI-based data acquisition and control system that provides the interface between the first two subsystems and the LabVIEW™ Virtual Instrument (VI) client that is used to perform the experiment in either local or remote (iLabs) mode. Components are housed in a PXI-1042Q chassis communicating with the local PC over a PXI-8360 interface card. There are 3 PXI-7330 motion control boards operating the stepper motors and associated limit switches, a PXI-6259 multi-function DAQ to receive signals from additional limit switches on the pneumatically controlled motions, a PXI-6521 8 channel relay card to drive the relays described above and a PXI-6602 timing I/O board to acquire time-independent counting data from the detectors (i.e. independent of the MCS system).

The Spectrometer client interface, called a Virtual Instrument or VI, was also implemented using LabVIEW® from National Instruments. LabVIEW is a graphical, event-driven programming package optimized for data acquisition, instrument control, and the graphical display of data. For this experiment, students need to download and install the LabVIEW® plugin for their browser.

Figure 4 shows the Spectrometer LabVIEW® client for the Maxwell Boltzmann Distribution Experiment otherwise known as the Time-of-Flight neutron physics experiment. In the client, students use the "Motion Control" area to position the Low Efficiency detector, control the choppers position and spin, and set parameters in the MultiChannelScaler (MCS) tab for the experiment. While the experiment is underway, students can watch the counts both by numbers counted in the Low Eff Detector Data field and graphically in the Waveform Graph of the Time of Flight data.

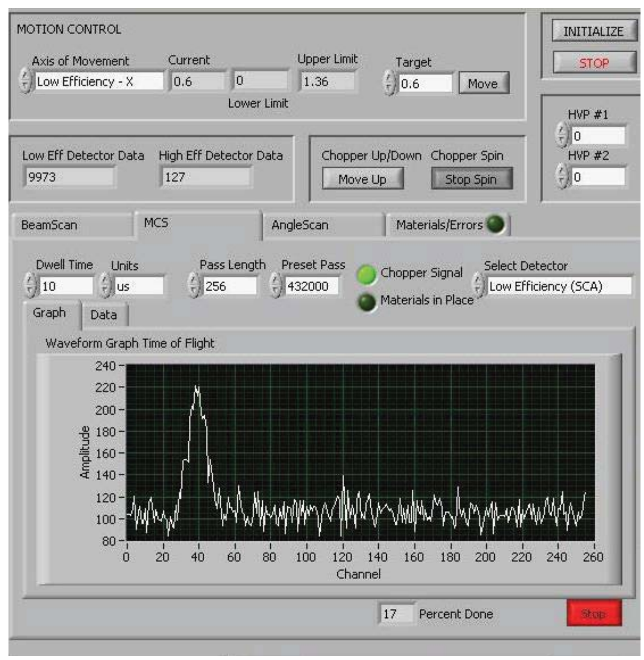

Figure 4. LabVIEW® client for the Maxwell Boltzmann Distribution Experiment otherwise known as the Time-of-Flight Neutron Physics Experiment.

V. RUNNING AN EXPERIMENT

The Spectrometer iLab is an interactive experiment that requires users to schedule experiment time in advance since typical experiment times can range from 20 minutes to 8 hours. Scheduling in advance ensures that the operators in the reactor control room can open the beam port. The beam port is only opened when an experiment is scheduled. Students typically work in teams of two or three.

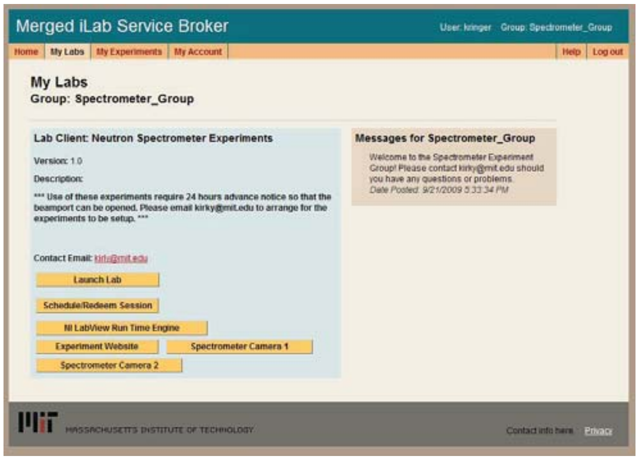

Figure 5. Student view of the Spectrometer experiment page on the Service Broker

To run an experiment, students login to the Service Broker, select the Spectrometer experiment group and redeem the reservation they scheduled in advance. The Service Broker checks to make sure that the user has a valid reservation and that he/she is authorized to use the Spectrometer experiment. The user is then presented with a "Launch Lab" button and is able to start the experiment client, as shown in Fig. 5. When the experiment is launched, the Service Broker facilitates the exchange of credentials so that the Lab Client running in the student's browser can talk directly with the Lab Server and experiment hardware. The LabVIEW™ client VI is launched from the LVILS Lab Server and displayed in the user's browser using a LabVIEW™ plugin. The client also establishes communications with the datasocket server so that experiment data can be stored in the database for later retrieval.

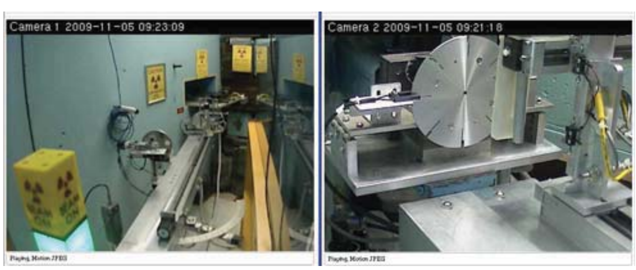

Figure 6. Spectrometer web camera views that enable the remote user to view the experiment while in progress.

The Spectrometer experiment installation has two web cameras available so users can watch the experiment while in progress. We have found that the cameras are essential to the student understanding and believing that they are working on and controlling real hardware. The first camera, Fig 6, is an overall view of the experiment and allows the user to watch the detectors and crystal as they are being moved. The second camera, Fig 6, is a close up view of the chopper wheel.

We have developed animations of each of the experiments to give the user a visual understanding of the phenomena being explored and the experiment being performed. Figure 7. Animation stills from the Spectrometer beam depletion experiment showing Aluminum and Polyethelene by R. Mark Bessette (MIT).

In this version of the Spectrometer client, shown in figure 4, the user can run any of the three experiments by selecting the correct tab. Before beginning any experiment, there are several steps that all users should take. First, the experiment hardware must be initialized. This will run an initialization sequence to make sure that all the components are in their correct starting positions. Second, students use the BeamScan tab to find the centerline of the beam, by moving the low efficiency detector across the beam port area. Users will see a peak in counts when the Low Efficiency Detector is centered in the beam. Once the user knows where the center of the beam is, they can position any of the components in the correct location.

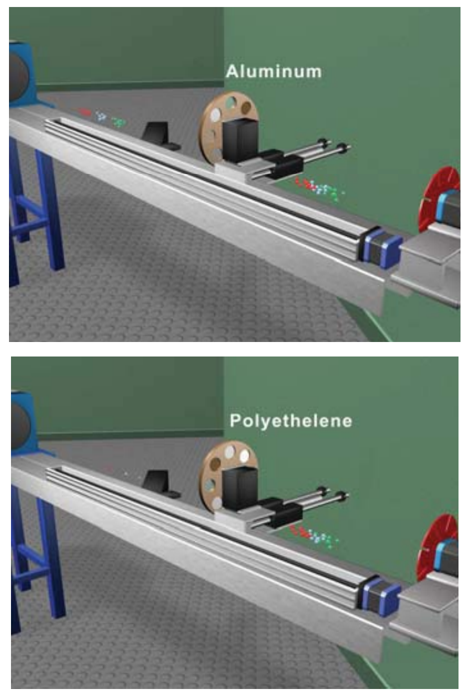

Figure 7. Animation stills from the Spectrometer beam depletion experiment showing Aluminum and Polyethelene by R. Mark Bessette (MIT).

In the time-of-flight (TOF) experiment, students use the MCS tab to perform measurements at two points (near and far) in the beam using neutron Low Efficiency Detectors and multichannel scalers. Utilizing the AngleScan tab, students can control the copper crystal's position and rotation as well as the high-efficiency detector angular position. In the Materials/Error tab, users can control the sample carousel and position various absorption materials into the beam for testing. A combination of hardware and software safety interlocks is used to avoid collisions of the movable components and to establish usable ranges for each experiment component.

VI. USAGE

Most of the usage to date has been by undergraduate students at MIT in the departments of Nuclear Science and Engineering (NSE) and Physics. These students generally have at least one "local" session at the experiment site before being offered the option to continue their work on-line. Approximately half the NSE students doing the lab as part of a required course used the on-line option, while the fraction was much higher for the Physics students. We attribute this largely to the fact that the NSE students do not perform the diffraction portion of the lab and thus require much less counting time than the Physics students. One of the clear benefits of online access is that the students accumulate counting data over much longer times and obtain better quality data sets that are more amenable to analysis. Students are also more likely to repeat experiments if data anomalies are discovered.

VII. SCHEDULING

Currently due to regulations and security issues and to avoid unnecessary activation of the beam components, the beam port is not open 24/7. The beam port is opened and closed manually by the operator on duty inside the reactor containment facility only when an experiment is scheduled. We currently add the scheduled experiments to the operator's schedule manually, that is to say, the Service Broker manager periodically looks at the scheduling calendar and tries to send an email at least 24 hours in advance to the reactor operator manager with a list of scheduled experiments and request that the beam port be opened. The Reactor operations manager then adds the beam port open and closes to the operator's schedule.

This process has several possible points where errors can occur. First, we request that students schedule their usage more than 24 hours in advance for weekday and no later than Friday midday for the weekend. We try very hard to work with the students to ensure they have access to the experiment, but this is sometimes an issue when a student makes a reservation through the Service Broker at 4:55pm on Friday afternoon for time on Sunday. There is no guarantee that the Service Broker manager will see the new reservation or that it can be added to the operator's weekend schedule. Second, the list of scheduled experiments is collated from the Service Broker by hand and sent via email. Sometimes this involves two or three email exchanges a day and sometimes emails are missed. And lastly, manual transmissions of schedules that pass daily through human hands are prone to transcription, typing or misreading errors. While we can not solve the regulatory and security issues, we hope to improve and automate part of the scheduling process in a future release of the Service Broker. We will be adding direct email notification to a mailing list (which will include the reactor operators) when an experiment is scheduled or changed. In addition, we hope to improve scheduling features to make it more user friendly and enable faculty and students to see who has the reserved time in case schedules need to be negotiated. Right now, reservations are on a first come basis.

VIII. FUTURE WORK

A variety of hardware upgrades are being planned or considered. A larger, more robust detector Z-axis motion slide with a higher power stepper motor would improve reliability of the system and reduce the required frequency of mechanical maintenance. The multi-channel scaler is fully controllable from within LabView™ and thus within the iLabs interface, but the "front end" of the nuclear counting system consisting of the high voltage power supplies and amplifier/TSCAs can neither be controlled remotely nor report their parameter settings to a computer interface. As new types of computer-based nuclear instrumentation become available, an appropriate replacement for the NIM electronics may be identified to provide this capability.

Some software improvements are also planned. Minor changes to the LabView™ interface will be made to incorporate suggestions from students and developers for improving appearance and easing navigation and operation. More substantive changes include the addition of counter/scaler and oscilloscope functionality to the interface. The counter/scaler would emulate the traditional hardware version with controls for counting time, single or repeat counts and automatic or manual count reset. This is a relatively minor programming effort because most of the functionality already exists in the Beam Scan and Angle Scan modules. An oscilloscope function that would allow on-line users to view the output pulses of the detector pre-amplifiers and amplifiers would be a significant enhancement to the on-line implementation and would be a preparatory step for putting the nuclear instrumentation under LabView™ control as discussed above. Some of the hardware required is already in place but additions would probably be necessary to allow switching the oscilloscope input between the low-efficiency and high-efficiency detectors.

ACKNOWLEDGMENT

The authors wish to thank our colleagues, Judy Maro, David Litster, Raymond Ma, Lin-wen Hu, Timothy Lucas, Meg Westlund and Maria Karatzas, whose vision, hard work and insights has guided successfully the development and deployment of the Spectrometer iLab.

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Session 01D Area 1: Computer and Web based Software - Web based services

Web-based Time Schedule System for Multiple LMSs on the SSO/Portal Environment

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A system to manage the alocation of MSc Dissertations at University of Minho

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Supporting the Delivery of Learning Contents with Laboratory Activities in SAKAI

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Web-based Time Schedule System for Multiple LMSs on the SSO/Portal Environment

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Abstract— **We developed a web-based time schedule system as an important feature of the university portal along with our university's long-term ICT (Information and Communication Technologies) plan. By using the system, students and professors can get their own course timetable in collaboration with the Student Information System (SIS). Each course name on the timetable is linked to the corresponding course page on the Learning Management System (LMS) through the Single Sign-On (SSO). The system is adapted to multiple LMSs which can be selected by the course professor. In order to widely cooperate with other systems, the system is designed by using global standards (IMS Enterprise, JSR-168 Portlet, etc.) and open source software (uPortal, CAS, JSF, Hibernate, etc.) as possible as we can. This paper shows the major functions, the measured use of the portal and the time schedule system over eight months, and the implementation especially for supporting multiple LMSs, syllabus and grade books.**

Keywords-timetable; schedule; LMS; Portal; SSO; IMS; CAS

I. INTRODUCTION

In recent yeas, the university's learning environment is becoming more and more convenient, effective and efficient by various ICT(Information and Communication Technologies)-enhanced systems, for example, Student Information System (SIS), Learning Management System (LMS), portal, e-Portfolio, electric library, etc.

Our university noticed that the quality of education and the university management can be improved through the appropriate ICT adaptation, and has established a long-term and university-wide ICT strategy (called the Integrated Campus Information System Plan) in 2001. Along with the plan, our organizations, the "Center for Multimedia and Information Technologies" and the "Institute of the e-Learning Development" were established in 2004 / 2008, and we have introduced various ICT systems.

Good collaborations among the systems should be very important to build ICT-enhanced learning environments. We therefore always try to use global standards and open source software as possible as we can for data interoperability and source transparency.

Along with the ICT plan, we developed a Single Sign-On (SSO) university portal for all students and staff since 2006 [1]. Once authentication is complete at entrance of the portal, user gets personalized web pages including information for each role, direct links to the available systems without re-authentication, etc.

As an important feature of the portal, we developed a web-based time schedule system placed on the portal as a tab page, where students and professors can get their own course timetable depending on their registration of the SIS [2]. Each course name on the timetable is directly linked to the corresponding course page on the LMS through the SSO.

Our university provides WebCT (now Blackboard LS) as a university-wide LMS since 2004. For the last few years, number of online courses has been increased and some professors requested to use different LMSs e.g. Moodle or Sakai. For this reason, we improved the time schedule system to adapt to multiple LMSs.

This paper will show the status of using the time schedule system and its new features not only as the multiple LMSs support, but also as functions of syllabus and grade books.

II. THE STATUS OF THE TIME SCHEDULE SYSTEM

A. *ICT-Enhanced Learning Environment*

Our university has been advancing the ICT-enhanced learning environment [3]. Better collaborations among the systems such as SIS, LMS, portal and many related systems, should be important to enhance the learning environment. We therefore developed the university portal for all students and staff (teaching, technical and administrative) based on the open source software (uPortal [4] and CAS (Central Authentication Service) [5]) and the original tools for connecting several university-wide systems since April 2006 [1]. Once authentication is complete, each user gets personalized web pages, including information for each role, direct links to available systems, the timetable linked to the corresponding course on the LMS, etc.

The uPortal is open source software and supports the Portlet (JSR-168 standard [6]) which provides pluggable user interface components to add functions to the portal. It not only ensures high portability but also it made us easier to add convenient functions specialized for each role, position, department, and so on (10,000 students and 2,000 staff).

The CAS is also open source software and it provides SSO environments. The university-wide LDAP is used as authentic data source for the CAS, users therefore can login wireless LAN, PCs for IT classrooms (1,300 PCs over the university with exactly the same usability), emails etc. with the same user ID and password as CAS as shown in Fig. 1. The CAS has been already supported by more than twenty systems, including both campus supports (library, carrier support, registrations, address book, etc) and learning supports (LMS, SIS, timetable, etc.) as shown in Fig. 1.

The time schedule system has been added to the portal since 2008, and where students get their own course timetable depending on their SIS registration. Each course name on the timetable is directly linked to the corresponding course page on the LMS through the SSO. Professors also can use their own timetable directly linked to the LMS course page as instructor and creator modes.

In the same time, we developed an IMS-capable [7] web-based management tool for synchronizing courses [8]. The tool provides functions of various queries by HQL, some IMS-type output files (courses, persons and cross-listed courses), and timetables for the queried persons with LMS access if possible.

We improved the time schedule system to support multiple LMSs as shown in Fig. 2, which describes data flows as the time schedule system are synchronized by the CSV data from the SIS and three LMSs (WebCT (now, Blackboard LS), Moodle, and partly Sakai) are synchronized by the IMS data from the time schedule system. Details will be shown later with the other new features.

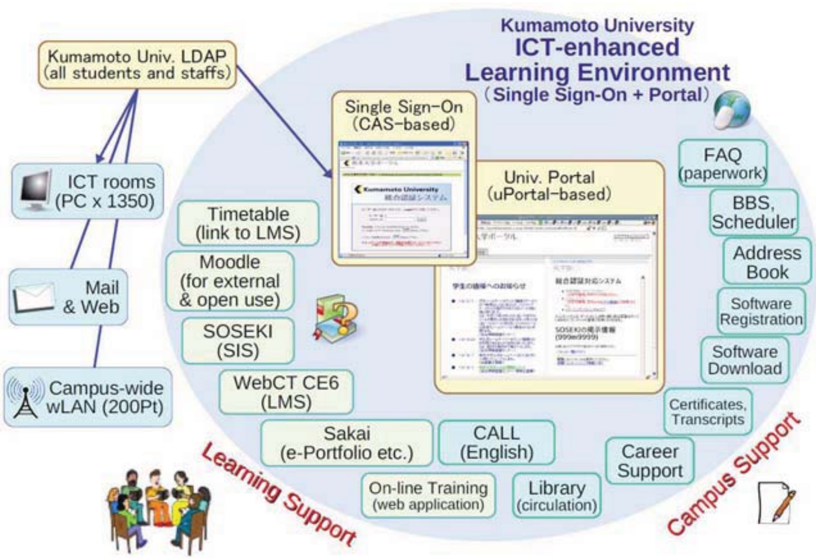


Figure 1. The Kumamoto university's ICT-enhanced learning environment with portal and the single sign-on system with web applications.

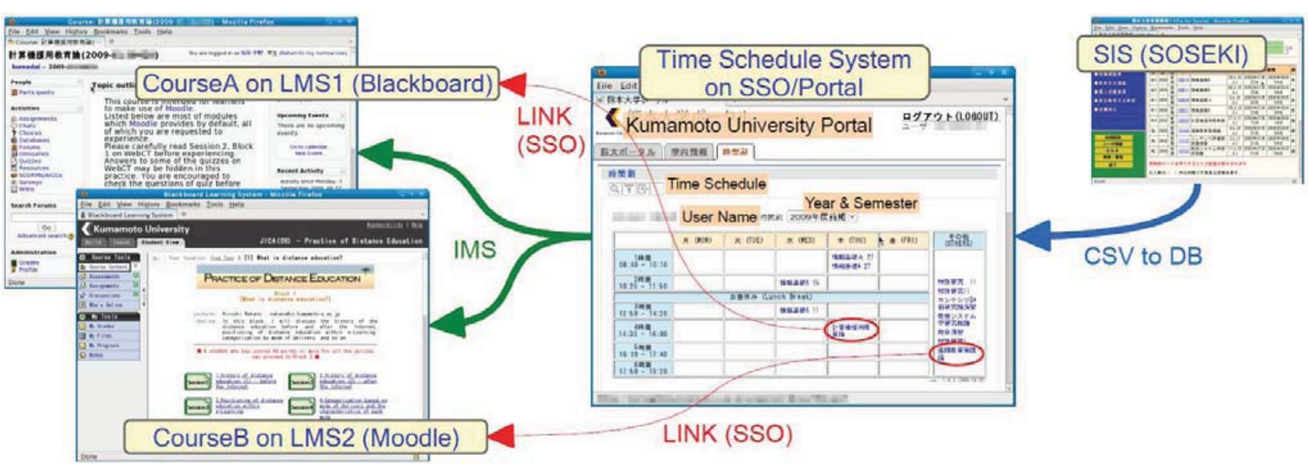


Figure 2. Data flow and SSO connections between the time schedule system on university portal, LMSs and SIS.

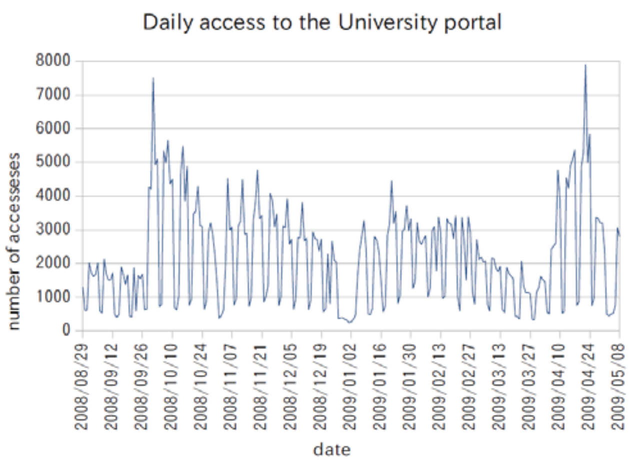
B. *Use of the University Portal*

Fig. 3 shows the use of the university portal. Left figure (a) shows the daily access number from August 29, 2008 to May 9, 2009 (for about eight months). The valleys are at the weekends and holidays as the New Year holidays. Almost all Japanese universities including us have two semesters in university year which start from April and October respectively. More than 7,000 accesses are observed at the beginning of the semesters, and a few thousands of accesses are on weekdays, and several hundreds of accesses still remain even on holidays as shown in Fig. 3(a). Because our university has about 10,000 students and 2,000 staff, we can say that the portal is used very well.

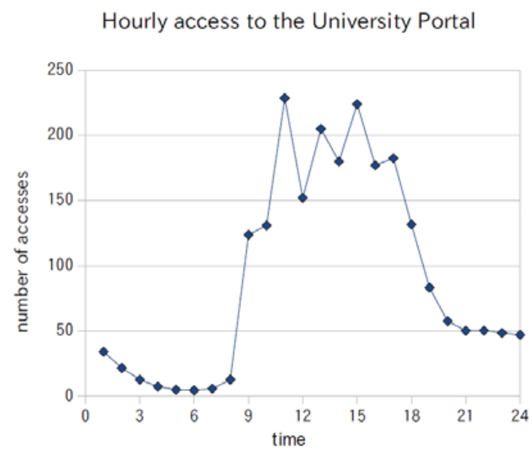
Fig. 3 (b) shows the hourly access number averaged for the same period. The curve of the daytime is not smooth, the reason is thought that many students begin to use the LMS through the portal at the beginning or break time of the courses. After 6pm, they are still using from their home and there are some accesses even in midnight.

C. *Use of the Time Schedule System*

Fig. 4 shows the use of the time schedule system. Left figure shows the daily access number from April 16, 2008 to October 31, 2009 (for about eighteen months). We can say that the time schedule system is also used well, because about 10 to 30 percents of the access of the portal are occupied by the time schedule system, in comparison between Fig. 3(a) and 4(a). The valleys are at the weekends as same as the portal. The largest difference to Fig. 3 (a) is that very low access areas can be found during spring and summer vacations. It means that users are accessing the portal even during the vacations, but they are not accessing LMS course contents through the time

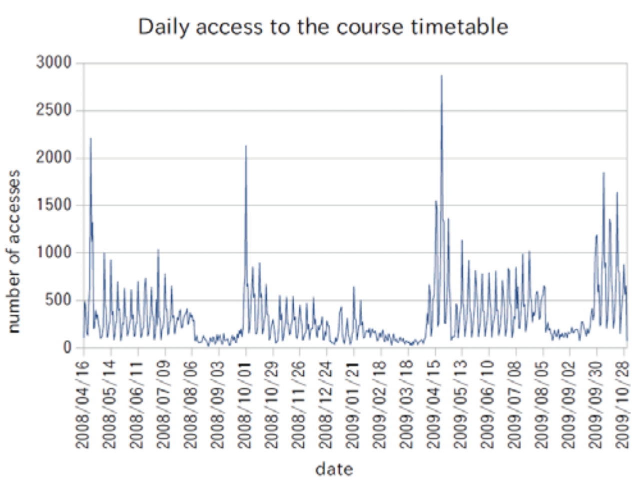


(a) daily access

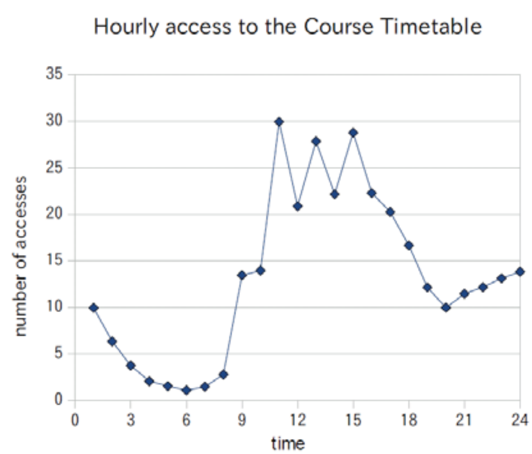


(b) hourly access

Figure 3. The use of the university portal.



(a) daily access



(b) hourly access

Figure 4. The use of the time schedule system.

scheduling system.

Fig. 4 (b) shows the hourly access number averaged for the same period. The averaged number of accesses seems to be low as the maximum is around 30, because of the very low access areas on vacations as mentioned. The curve of the daytime is also not smooth as same as the portal. After 6pm, the curve increased again, but we could not find the reason yet. In ether case, students are still using the system even at midnight from their home.

III. THE IMPLEMENTATION OF THE TIME SCHEDULE SYSTEM

A. *Developing and Running Environment*

The WebCT CE6 (Blackboard LS 6), the Moodle 1.9 and the Sakai 2.6 are targets for supporting multiple LMSs now. Our sakai support is still experimental because the courses can not be synchronized yet (only manual registration is possible).

As many users (more than 300 in the maximum case) are accessing at the same time, a relational database is used for extracting a schedule quickly for each user. User profiles and registered course information are daily synchronized from SIS to the system by CVS format, and also synchronized from the system to LMSs by IMS Enterprise format [7] as shown in Fig. 2. The WebCT and the Moodle support IMS format and all the courses are synchronized daily. WebCT does not support CAS, and we therefore developed adapters using the portlets for the Blackboard LS [9]. The system is developed by using fully open source tools; Hibernate and JSF on J2EE (Tomcat), and MySQL.

B. *The Course Timetable*

Fig. 5 shows a course timetable example on the university portal for some student. The "(e) Course timetable" shows the timetable unique for the students ID, the semester and the year. The timetable can be changed to the other one for different semester and year by using the selection box "(d) Select Year & Semester". The view of the checkboxes (f) is adjusted for the role of students / professors and on- / off-campus as shown in Fig. 6. The score icon can be shown only on campus, and the setting icon can be shown only for professors. All enabled check box can change the state (show or hide each icon) of all cells of the timetable.

Figure 5. Course timetable on the university portal.

Figure 6. Four cases of the check box (f) in Fig.5.

Figure 7. The course setting menu for professors.

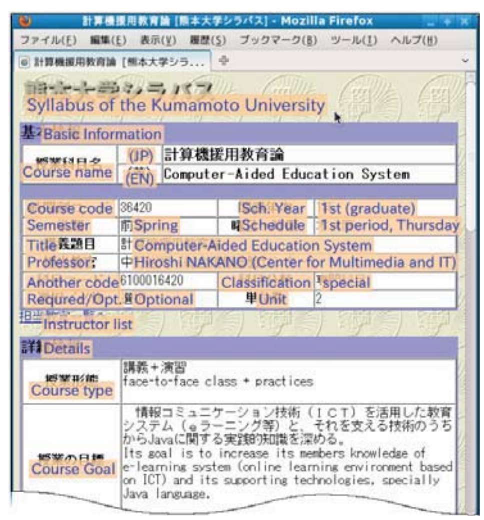


Figure 8. The syllabus for the selected course.

C. The Course Setting Menue

Fig. 7 shows the course setting menu for the professors when they click the setting icon (shown in Fig. 6 (c)) on each cell of the timetable. The professor can select one from four choices; WebCT, Moodle, Sakai and “not using”. WebCT is the current default value, and once professor select Moodle or Sakai, all students and professors will jump to the selected LMS when they click the course name in the cell of the timetable. If professors select the “not using”, the course name's color will change to black without any links. These settings can be reset or changed anytime from this menu.

D. The Syllabus Icon

When students or professors click the syllabus icon (shown in Fig. 6) on each cell of the timetable, the syllabus of the course will be shown in a new window (Fig. 8). Our university open all syllabuses over the Internet and this system simply jump to the corresponding syllabus page directly for convenience. On the syllabus, students can get whole course information as shown in Fig. 8 (translated).

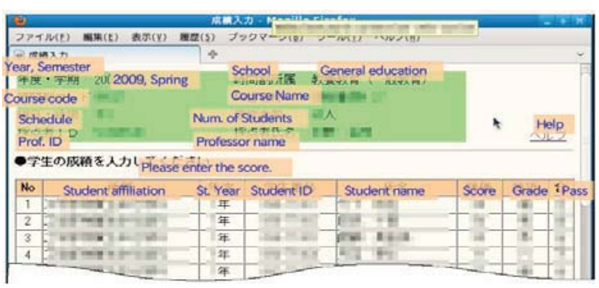
E. The Score Icon

When students or professors click the score icon (shown in Fig. 6) on each cell of the timetable, the grade-book page of the SIS system will be shown in a new window (Fig. 9, translated). For students, they will get the score list of the grade book corresponding to the semester as shown in Fig. 9 (a), where they can check their course scores for the semester. The grade book of the current semester may not have no meaning except on the end of the semester, but previous semester's ones are meaningful and it can easily shown by the selector “(d) Select Year and Semester” in Fig. 5 anytime.

For professors, they will get the students list of the corresponding course with scores as shown in Fig. 9 (b), where they can not only see but also enter or edit scores for each student.

The score function is limited to use only on campus, because of the security policy of the SIS system.

(a) for students



(b) for professors

Figure 9. The grade page from SIS.

IV. Future Plan

The time schedule system has been used university-widely more than three semesters (eighteen months) as shown in Section II, and we have already improved several points as supporting the multiple LMSs, the syllabus and the grade-book, with fixing bugs. We have several valuable comments from users, and some ideas to do.

Now we are using the university-wide course timetable, but we do not have university-wide calendar as a function of group wares. We are planning to introduce a university-wide group ware for staff and students, where the all functions of the current course timetable had better to be available on a calendar with additional information, e.g. the class subject on the date, planed examinations, cancellation, etc.

Some students asked us to use the grade-book function through the Internet (outside of the campus network), because they want to know the scores far from the campus during vacations between semesters, when they go back to their born place or stay their internship place, etc. We therefore have a plan to provide the grade-book function with limited information over the Internet, by developing a secure intermediate server which keeps only limited information synchronized to the SIS.

Some professor gave a valuable comment that he wants to use the time schedule system for leading or counseling students if he could see the course timetable of the specified student with each course scores, because he can find easily subject, time and semester dependency of the student activity. We have a plan to add a counselor mode to the system for designate persons.

V. Conclusions

We developed a web-based time schedule system as an important feature of the university portal along with our university's long-term ICT plan. By using the system, students and professors can get their own course timetable in collaboration with the SIS. Each course name on the table is linked to each course contents on the LMS through the SSO.

We developed the system based on open source software and global standards as possible as we can for data interoperability and source transparency in order to connect several systems in standard and portable ways.

The use of portal and the time schedule system were measured for about eight and eighteen months respectively. The result shows that the both systems are used well even on holidays or at midnight from homes, and reflect students' activities in weekly, daily or hourly.

The system is adapted to multiple LMSs; WebCT, Moodle, and Sakai (experimentally). The LMS can be selected by the professor for each course. The time schedule system also provides the functions of showing syllabus and scores of the course. All these functions can be selected whether visible or not.

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A system to manage the allocation of MSc Dissertations at University of Minho

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***Abstract*—This paper describes the basis for the specification of an IT infrastructure, supported by a website, designed to manage the entire paperwork process associated with the management of Masters Dissertations. With this infrastructure it is possible to disclose the subjects offered, to allocate each subject to a candidate - "dissertations in progress", browse dissertations that are awaiting review and consult the archive of dissertations with exams already carried out. PostgreSQL technology was used to support the databases. This technology was chosen to be robust, with easy integration with PHP and its code is open source. The website is housed in a Linux server based infrastructure ready to run continuously.**

Keywords – CMS – Content Management System, Website, Backoffice, Frontoffice, PHP, Bologna Process, Dissertation

I. Introduction

The higher education systems have undergone great challenges in the last decades, initially motivated by the growing up number of students. Currently, the importance of communication technologies is found in the strong dissemination of knowledge, which has been taking place in the European systems, through the Bologna Process. The Bologna Process is named after the Bologna Declaration, which was signed in the Italian city of Bologna on June 19th of 1999 by ministers in charge of higher education from 29 European countries [1].

The Bologna Declaration leads to the adoption of a system essentially based on two main cycles, undergraduate and graduate. The access to the second cycle hall requires successful completion of first cycle studies, lasting a minimum of three years. The second cycle should lead to the writing of a master thesis.

The dissertation topics are proposed by the advisors. The students then choose one topic from the whole list of topics available. When a dissertation topic is assigned to a given student, by his supervisor, the work process starts and lasts until the dissertation report is finished. After the supervisor approval, the dissertation is submitted to an examination which will be evaluated by a jury that will award a final mark. Finally, after the exam, the dissertation document is put in an electronic archive.

In order to manage this process an information system based on a website has been created, using the PHP programming language [2]. The website is divided into two main components: the Frontoffice and the BackOffice.

A. Frontoffice

This structure enables the students and the public to browse dissertation subjects offered by supervisors, the dissertations that are in progress, the ones that are waiting review and the archive of the dissertations already carried out. A news area is also available where the site administrator can broadcast some pertinent alerts and events related with the course. In order that a visitant can easily find a particular topic, a search engine was developed since the amount of information is growing everyday.

B. Backtoffice

This is a CMS (*Content Management System*) that is supported through a database (whose relation model is showed in figure 13).

The CMS enables the creation of a hierarchical structure of users, with different types of privileges, in order to manage the introduction of different kinds of data. Its main features are:

- The administrator is the one that has privileges to create the other users (supervisors) and each user is responsible to manage data related with the dissertations for which he is responsible. All users may introduce personal data associated with a particular student, but when a student is allocated to a specific user only this user and administrator can change this record.
- A file upload system was built since it is necessary to attach some other useful information supported in files (e.g. Photos, PDFs).
- In order to produce the student invoice form it was developed a tool that collects all the information related with the student (e.g. identification, address, birth, contacts, photo), the dissertation subject (e.g. description, objectives, tasks, schedule), the supervisor and other institutional data to produce a PDF file with a layout in accordance with the administrations office.

The remaining blocks of the CMS support the introduction of contents that can be assessed through the Frontoffice.

II. FRONTOFFICE DESCRIPTION

The Frontoffice is a web based system that provides an interface to the students and supervisors in order to manage the dissertation process. The structure of the Frontoffice is composed by the following areas:

- Proposals: subjects offered by supervisors,
- Dissertations: dissertations in progress,
- Archive: dissertations already carried out,
- News: page to broadcast news,
- Documents: download area. Here are available all the files related to the registration process, assessments and some other logistics tasks,
- Search: typical search engine in order to easily find some particular topic (e.g. "find all topics proposed by a particular supervisor").

Fig. 1 shows the Frontoffice Homepage:

Figure 1. Frontoffice's Homepage.

The menu bar located at the top of the page is composed by the buttons to access all the areas mentioned above. There is also a button ("Backoffice") that opens a new window to Backoffice access.

The News area is located at the left side of the page. An event, an alert or a deadline can be announced here. The news structure has the following fields: Title, Date, Text and a Picture (optional). Only the first 25 words are displayed in the Homepage. To access to the whole news text it is necessary to press "more".

The right side of the screen is designed to show the last introduced proposals by the supervisors. When an exam is at a distance of 1 week, the right part of the screen is subdivided into two parts (fig. 2). Upper part has the reference(s) to the dissertation(s) (Title, Student Name, Exam date, Room and time). To access to all details of the dissertations (including the full text in PDF format) the user must follow the corresponding link.

The page showing dissertation details is presented in fig. 4.

The remaining lower part of the page displays the last introduced proposals by the supervisors.

Figure 2. Frontoffice's Homepage. The right side of the page is now splitted into two parts to announce the upcoming exams.

The next area that can be accessed through the menu bar is the "Dissertations Proposals", by pressing "Proposals" button. The page is shown in fig. 3.

Figure 3. Dissertations Proposals list.

The result is a list of topics disposed by scientific areas. For each topic the Supervisor Name, the Title and the Submission Date are displayed.

In order to view each proposal details, the user must press "Detail". The result is shown in fig. 4.

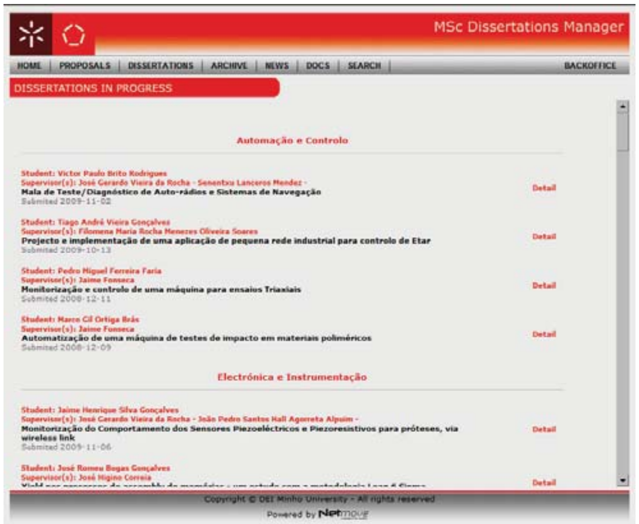

Figure 4. Dissertation Proposal details.

This page displays the full record of a chosen proposal. In fig. 4 we can see an example. The fields associated to each proposal are:

- Supervisor Name,
- Supervisor Email,
- Summary,
- Objectives,
- Keywords,
- Useful Links.

These fields must contain all the information that a student needs to select the theme that better fits to his skills and knowledge. After that, the student contacts the supervisor responsible for the chosen topic and discusses with him about the possibility (or not) of modifying the proposal in order to better fit the student profile. The result is then published in the Dissertations area.

The Dissertations area is similar to the Proposals area. The record structure contains all the fields (copied form the Proposals area) and other fields related to the allocated student:

- Student Number,
- Student Name,
- Student Email,
- Starting Date.

When the work is terminated the student writes his dissertation and a jury, recommended by the Department's Academic Board, is appointed. The Jury is usually composed by the student's supervisor, the head of department and an invited professor from another department or faculty, that will be the Reporter of the examination. At this time some more information are appended to the Dissertations area:

- Reporter Name,
- Reporter Email,
- Exam date,
- Exam location,
- Dissertation text in PDF format.

Fig. 5 shows an example of a Dissertation page in full format:

Figure 5. Dissertation page in full format.

This page is displayed in the Dissertations area until the exam date is reached. After that, this record is moved to archive. The layout and the information remain the same as previously, but the record belongs now to Archive area.

The News area consists of a page where the news, listed in reverse order of entry, are displayed in the same way as in fig.1, but now enjoying the whole space of the page.

The Documents area is a file repository that stores some useful forms, templates, tutorials and some dissertation rules and guidelines to help and support students during the whole process.

Finally, pressing "Search" at a menu bar, a page with a search engine is accessed (Fig. 6). This page is very useful since the amount of information is growing quickly.

Here it is possible to find dissertations or proposals. The search can be done by Student or Supervisor names, Scientific area or a given keyword.

Figure 6. Search engine page.

III. BACKOFFICE DESCRIPTION

The Backoffice is CMS that manage all the information that can be accessed by the Frontoffice. The login page is accessed by pressing the “Backoffice” button located in the right corner of the menu bar. The Login page is shown in fig. 7.

Figure 7. Backoffice Login page.

By entering the user’s email and password, the system goes to the Backoffice Homepage. Fig. 7 shows that homepage when a user is logged in.

Figure 8. Backoffice Homepage (user).

The Menu bar is composed by five buttons:

- Proposals,
- Dissertations,
- Students,
- Reporters,
- Personal data.

The Proposals area is a page that contains a form with the fields required to be filled with the information related with the proposed work. Fig. 9 shows the Proposals page.

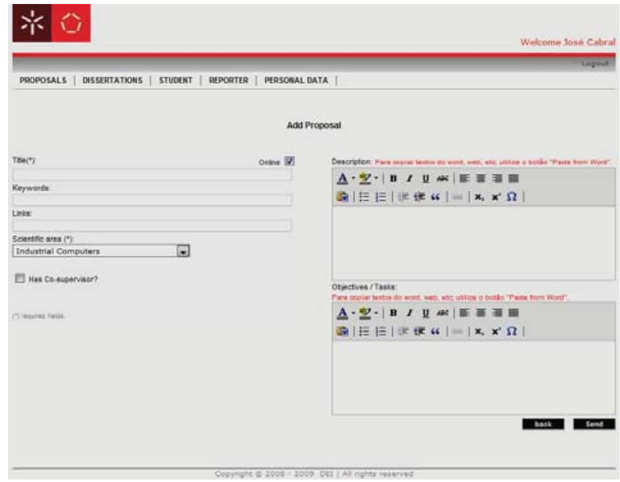

Figure 9. Proposals page.

The text inserted in fields “Description” and “Objectives” could be formatted using an editor tool visible at the right side of fig. 9. The other fields are inserted using basic text boxes. There is also a checkbox (“offline”) to show/hide the proposal in Frontoffice.

The Dissertations page structure contains all the fields of the Proposals page and other information related with the student. When a student has finished his work, the supervisor activates a checkbox to define the exam schedule. This action expands the form in order to insert other fields associated with the exam:

- Exam Date,
- Room and Time,
- Reporter name,
- Upload PDF.

Fig. 10 shows the expanded Dissertations page layout.

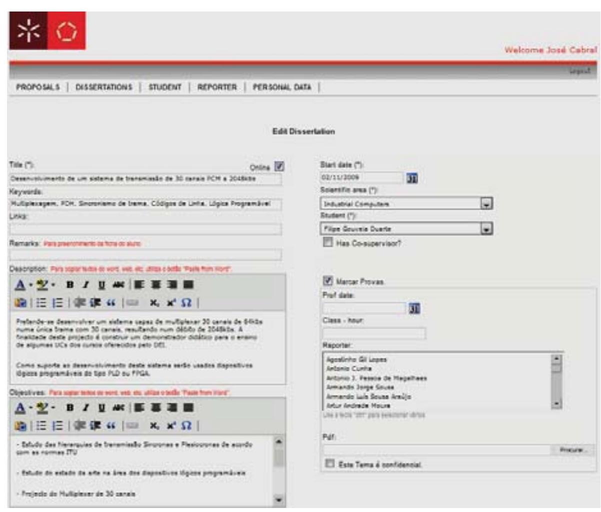

Figure 10. Dissertations page (expanded).

The next item at the Menu bar is the "Student" button. Pressing this button the system displays the page shown in fig. 11.

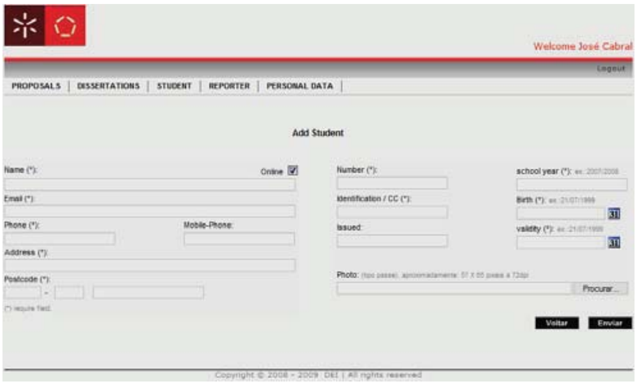

Figure 11. Student page

In this page there is a form to introduce the student data as well as an upload box to collect the student photo.

The remaining buttons of fig. 9 ("Reporter" and "Personal Data") are also forms to introduce personal information about the reporter of the exam and the user, respectively.

Since the Administrator needs additional tools in order to create, delete or change settings of regular users, create news and change a user profile, his menu bar has more buttons when compared with the one of a normal user. Moreover, a user with an administrator profile may access to the information introduced by all users. Fig. 12 shows the Backoffice´s Homepage in this case.

Figure 12. Backoffice Homepage (Administrator).

The extra buttons are:

- Personal Data,
- News.

The first button also appears when a normal user is logged in but, in this case, the Administrator has a tool that allows him to create new users with one of two profiles: "Normal user" and "Administrator". The second button produces a form that allows him to introduce the texts and the images associated to the news area of the Frontoffice.

IV. Supporting Technologies

System development was supported mainly by two technologies: PHP and PostGreSQL, described in the next two sections.

A. PHP

PHP (Hypertext Preprocessor) is a widely-used general-purpose open source scripting language that is especially suited for Web development and can be embedded into HTML (Hypertext Markup Language) [2]. PHP is mainly focused on server-side scripting and so it can do anything any other CGI (Common Gateway Interface) program can do, such as collect form data, generate dynamic page content, or send and receive cookies. There are three main areas where PHP scripts are used:

- Server-side scripting. This is the most traditional and main target field for PHP. There are three things to make this work: the PHP parser (CGI or server module), a web server and a web browser. When the web server is running, with a connected PHP installation, the PHP program output can be accessed with a web browser, viewing the PHP page through the server.
- Command line scripting. A PHP script can run without any server or browser. In this case it is only necessary the use of a PHP parser. This type of usage is ideal for scripts regularly executed using cron (on Unix or Linux) or Task Scheduler (on Windows). These scripts can also be used for simple text processing tasks.
- Writing desktop applications. PHP is probably not the very best language to create a desktop application with a graphical user interface, but for those who know PHP very well, and would like to use some advanced PHP features in client-side applications, they can also use PHP-GTK to write such programs.

One of the strongest and most significant features in PHP is its support for a wide range of databases. Writing a database-enabled web page is incredibly simple.

B. PostgreSQL

PostgreSQL is a powerful, open source object-relational database system. It has more than 15 years of active development and a proven architecture that has earned it a strong reputation for reliability, data integrity, and correctness [3]. It runs on all major operating systems, including Linux, UNIX and Windows. It is fully ACID (Atomicity, Consistency, Isolation, Durability) compliant, has full support for foreign keys, joins, views, triggers, and stored procedures (in multiple languages). It includes most SQL:2008 data types, including INTEGER, NUMERIC, BOOLEAN, CHAR, VARCHAR, DATE, INTERVAL and TIMESTAMP. It also supports storage of binary large objects, including pictures, sounds, or video. It has native programming interfaces for C/C++, Java, .Net, Perl, Python, Ruby, Tcl, ODBC, among others, and exceptional documentation.

An enterprise class database, PostgreSQL boasts sophisticated features such as Multi-Version Concurrency Control (MVCC), point in time recovery, tablespaces, asynchronous replication, nested transactions (savepoints), online/hot backups, a sophisticated query planner/optimizer, and write ahead logging for fault tolerance. It supports international character sets, multibyte character encodings, Unicode, and it is locale-aware for sorting, case-sensitivity, and formatting. It is highly scalable both in the sheer quantity of data it can manage and in the number of concurrent users it can accommodate. There are active PostgreSQL systems in production environments that manage in excess of 4 terabytes of data.

PostgreSQL's source code is available under the most liberal open source license: the BSD license.

V. SUPPORTING DATABASE

The supporting database was implemented in PostgreSQL whose relation model is shown in fig. 13.

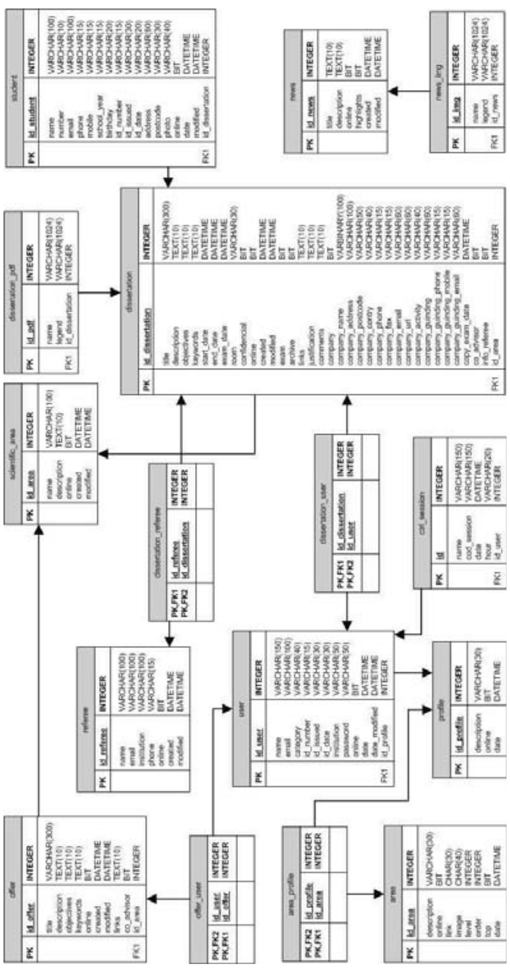

Figure 13. Database relational model.

This model is fully normalized and, thereby, ensures that the information will not be lost or duplicated. The model consists of 16 tables and could be divided in three groups.

The group, composed by tables: user, area_profile, profile, area, student and referee stores information about system users and are classified through a user profile with different privileges. Thus, it is possible to ensure that data entered by a particular user will not be corrupted by misuse.

The group, composed by tables: offer, dissertation, dissertation_pdf, scientific_area, news and news_img is responsible to store information that can be accessed in the Frontoffice such as: Proposals, Dissertations and News.

The other tables are used to troubleshoot impossible relationships in the system.

VI. CONCLUSIONS

The specification of an IT infrastructure supported by a website, designed to manage the paperwork process associated with Masters Dissertations is described in this paper [6]. The infrastructure is composed by two main areas: the Frontoffice and the Backoffice. The first one allows all the people to browse the information about the past and present master thesis, whereas the second one allows the responsible people to introduce the information. PostgreSQL database manager with integration with PHP in a Linux server were used as supporting technologies. The system is full working at the University of Minho, having at this moment 230 registered Master students and dissertations.

ACKNOWLEDGMENT

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Supporting the Delivery of Learning-Contents with Laboratory Activities in Sakai

Work-in-Progress report

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***Abstract*—Educational and training-providinginstitutions are increasingly depending on the web-based *Learning Management System* (LMS) for delivering course-contents in both on-campus and distance classes. This system offers an easily-accessible environment with various tools for managing learners and courses, and for producing rich contents. However, beside the rich contents, certain fields of study require that courses be accompanied with/followed by laboratory activities which help learners deepen their understanding of the new concepts and develop skills on applying them in close-to-real-world context. More emphasize has been put on these activities when laboratory-based courses appeared and proved to be functioning well in delivering the information. Several stand-alone laboratories have been constructed to support delivery of such activities on-line, but laboratory-tools are not available within the LMS. To address this point, our research presents an approach towards integrating one stand-alone laboratory (NVLab) into Sakai LMS to enable the use of laboratory activities within the course context. The study suggests integrating parts of the original system into Sakai, and then using the LMS's "*linktool*" to connect to the other part. So far, an initial version of the new tool has been accomplished and we are in the testing phase of the new tool on a demo version of Sakai before putting it into service within the campus-wide system.**

Keywords- K3.2 Computer and Information Science Education; K3.1.d Distance Learning; Web-based Laboratories; Learning Management Systems

I. INTRODUCTION

Dependence on web-based *Learning Management Systems* (LMS) is increasing in educational and training-delivery institutions. These systems are used not only with online-courses, but also with those delivered on-campus.

Web-based LMS is easily-accessible and incorporates tools for managing courses, learners, grades…etc, and other tools for supporting the learning process. The later are designed to assist in producing rich contents and to facilitate the interaction among learners and between them and their instructors.

In many cases, what the LMS offers is enough for building an innovating class structure; however, in certain fields of study more is required for successfully delivering the information and building the learners' capacity for real world context. This is certainly true for *Information and Communication Technologies* (ICT) courses where laboratory activities are necessary for deepening the understanding and building skills for applying the concepts being introduced [1]. Instructors put further emphasis on such activities when they successfully introduced on-campus laboratory-based courses [2].

Since current LMSs lack the capability to offer experience-building tools, and to address the need for incorporating laboratory-facilities within online courses, stand-alone web-based laboratories came to existence in a wide range of engineering fields-of-study. Examples of such systems include those which used on-campus facilities equipped with access-networks [3] [4], and others that used modern technologies for constructing the laboratory [5] [6] [7]. This arrangement worked well for classes structured in the conventional way where students get the information first and later apply what they have learnt in the laboratory.

But in contexts where carefully-designed dynamic-contents/practical-activities were combined with the course static-contents it was proven that learning-performance was better in engineering and medical sciences [8] [9]. This, in addition to the success of laboratory-based courses, indicates the importance of building a tool for either integrating practice-acquiring facilities into the online-course, or linking the stand-alone laboratory with the LMS.

- *Paper contribution*

In this paper, we demonstrate our technical approach towards integrating a stand-alone web-based laboratory (NVLab) that we already built for supporting courses concerning *Computer Networks* into Sakai LMS. We suggest:

- Integrating the tool the learners used for producing a network-design in NVLab into Sakai. and
- Using the LMS's *linktool* to enable them access the networks corresponding to their designs which the system constructs on separate servers.

The rest of the paper is organized in sections as follows: section II provides brief background about NVLab and Sakai, and section III presents technical description of the new system development process and requirements. Then in section IV we introduce the task-flow of a simple exercise that we designed for testing the new system within Sakai. Finally, we end with our conclusions in section V.

II. BACKGROUND

NVLab [10] is a web-based laboratory that we designed for supporting online courses concerning *Computer Networks*. It introduces to the learners a tool for producing a network drawing, then uses *Virtualization (Xen)* [11] technology to realize this network on a single server by instantiating *Virtual Machines* (VMs) that correspond to the devices included in the network diagram. Learners are able to remotely access the VMs' terminals via the *Virtual Network Computing (VNC)* [12] [13] module (vnc-server) running on the server.

Students are able to use NVLab for constructing networks, trying to apply what they have learned, and finding out what problems may rise with their designs. Instructors, on the other hand, use it for producing properly/improperly configured network designs and ask the learners to verify/troubleshoot the settings of the devices included in these networks.

We introduced a sample exercise on IP-addressing to a group of learners and asked them to use NVLab to complete it and provide feedback on their experiences using the system. The participants in this experiment completed the exercises successfully and commented positively on the system [10]. Figure 1 shows a screenshot for a learner's machine while connected to NVLab.

As mentioned before, our goal is to have a new laboratory-tool to be used with online courses. For this, we decided to use NVLab and Sakai LMS [14]. Sakai has been selected for some specific reasons: 1) it is an open and freely available LMS that is kept by a community on the Internet; 2) it is evolving all the time and the number of organizations implementing it is increasing; 3) Sakai is written in Java language which is the same used in NVLab and this would make our progress faster.

Courses in Sakai are created using *Sites*, and each *Site* is a workspace that has a number of tools available for all participants. Figure 2 shows one course-*Site* titled *ComNet* which uses Sakai's *web-contents* tool for introducing some information related to *Networking in Java* from Sun website [15].

Tools available in Sakai are of wide range to cover the students' and faculty staff needs. These include: general collaboration tools (like *resources*), teaching and learning tools (like *syllabus*), portfolio tools (like *reports*), and administrative tools (like *users*). The instructor has the right to include the tools he/she sees necessary for conducting the various tasks within the course from Sakai's rich tool-pool.

III. TECHNICAL DESCRIPTION

Incorporating the laboratory system as new tool in the LMS will enable us:

- Leave all administrative tasks, previously considered in NVLab, to Sakai.
- Save information necessary for tracking the learner's advancement while progressing through the course.
- Replace the VM-management solution, *virt-manager* in NVLab, which learners found difficult to use with another application that introduces a web-based interface.

- *System Description*

NVLab (Figure 3) comprises 3 main parts: 1) the *virtual network*, which the learners create, 2) tools for producing the network (*Designer* and *Builder*), and 3) tools for accessing/managing the network (*vnc-server* and *virt-manager*).

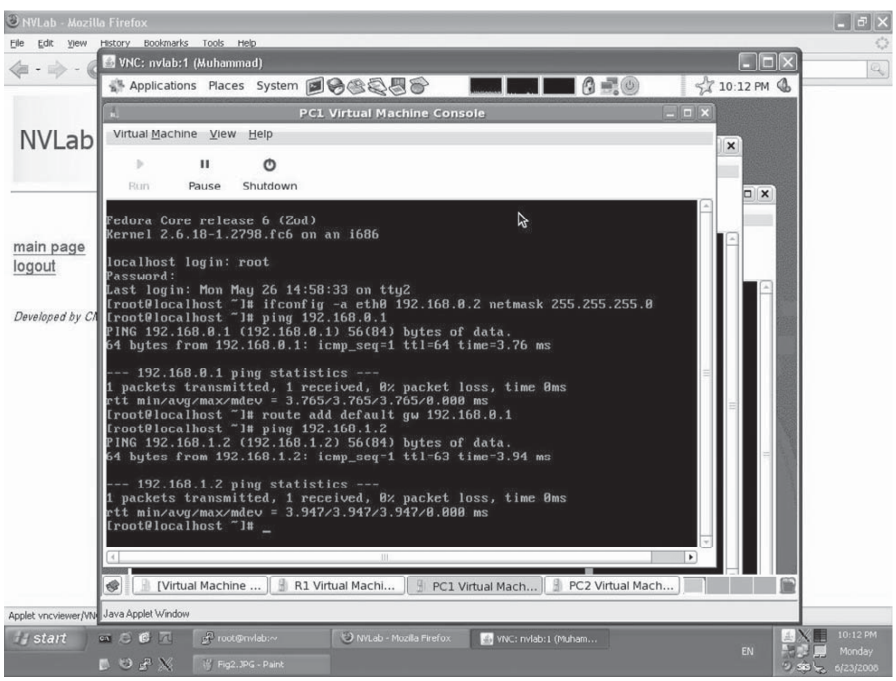

Figure 1. Learner's machine when logging into NVLab

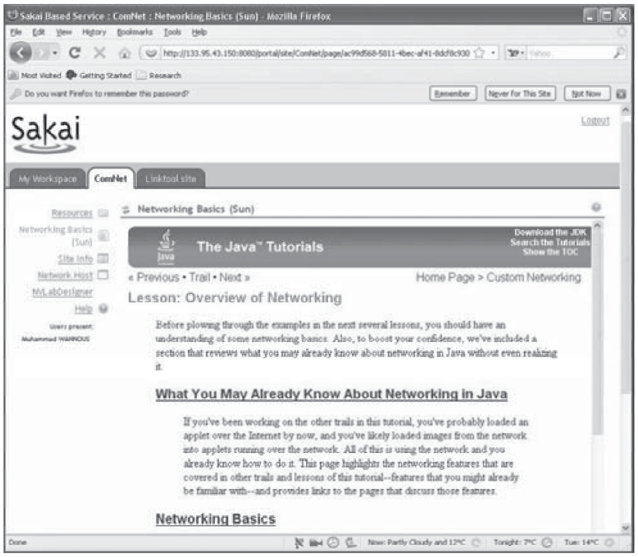

Figure 2. One course-*Site* in Sakai

We introduced two new tools within NVLab: *Designer* (Java Applet) and *Builder* (Java Servlet). A learner used the former tool to draw a network diagram and to save this diagram on the server side; then he/she invoked the later tool which used prototype VMs to create the network on the server. When the first phase is completed, a learner was able to connect to the machine hosting his/her network using the web-browser, and then used *virt-manager* to manage the VMs and start working on their configurations.

The new system has almost the same structure except that parts of it have been integrated into Sakai as shown in Figure 4. In the new arrangement, the laboratory comprises 3 main parts also: Sakai, *NVLabManager,* and a pool of *NetworkManager* servers. Network-designs are drawn in Sakai, while the system creates each of these designs on one *Networkmanager* server. *NVLabManager* works as a check point and server-pool controller /access mediator.

On Sakai side learners use *Nvlabdesigner* to draw a network diagram and save it as an xml-file in the course-site *resources*. This is a tool with GUI interface that enables producing a graphical representation of a network as shown in Figure 5. Copies of the network-diagrams generated by the students are also saved in a hidden space where only the instructor can access them for monitoring the learners' progress. When invoked from *NVLabDesigner* webpage*, createNetwork* Servlet reads the newest xml-file from the *resources* and sends it to *NVLabManager*.

NVLabManager keeps records of the users holding permission to use the laboratory and the servers available for the learners. It assigns one free *NetworkManager* server to the student when it receives a new diagram xml-file, and frees this server when the learner has finished his/her work. In this web-application, *serverManager* Servlet receives the xml-file, verify the user permissions, assign a free server to the user, and then redirect the xml-file to that server in order to create the network contained in it. *NVLabManager* also works as a gateway for accessing each *NetworkManager* through Sakai *linktool*.

Actual work is done on *NetworkManager* where the *Virtual Network* resides. The *netCreator* creates the *Virtual Network* by instantiating VMs from a VM-pool available on each server, and then starts them in preparation for incoming connection from the user side. Creating each VM involves: 1) moving a file that acts as a storage medium for the OS running inside the machine, 2) writing a configuration file that defines the resources available to it (sample is shown in Figure 6.), and 3) writing an html file that contains the definition of a VNC Applet that is used to view the VM's terminal window. The Applet takes one parameter that indicates the TCP port number to which the terminal window is bound (sample html file is shown in Figure 7).

The other Servlet called *netManager* receives the connection initiated from Sakai *linktool* included in the course *Site.* This Servlet is partially based on a web-based Xen VM management tool [16] that we previously introduced. n*etManager* provides a simple web-interface for managing the VMs in the *Virtual Network* as shown in Figure 8. In this interface, links to the html files previously created by *netCreator* are included. When accessed via these links, the learner will get a view like the one shown in Figure 9.

- *Development Environment*

Current work has been done and tested using: Sakai 2.5.4 demo version [17], the famous web-application container Tomcat Apache 5.5.25 [18], Eclipse IDE [19], and NetBeans 6.5.1 IDE [20].

Sakai developers considered that many instructors may wish to build tools that better meets achieving certain functions in the course, and therefore introduced many useful information/software pieces that simplify this task. One simple Sakai tool is considered to be a web application with special configuration file that instructs Sakai to include this application within its pool. To develop *NVLabDesigner*, we used *AppBuilder* available from Sakai developers' community [21].

IV. Task Flow in a Sample Exercise

Considering a course on *Computer Networks* where learners are supposed to gain complete understanding of IP

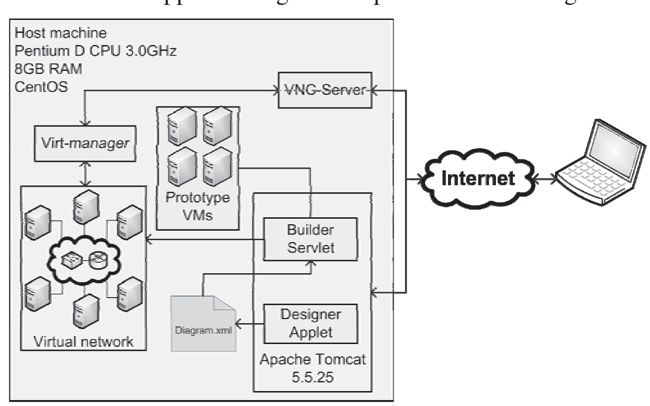

Figure 3. NVLab structure

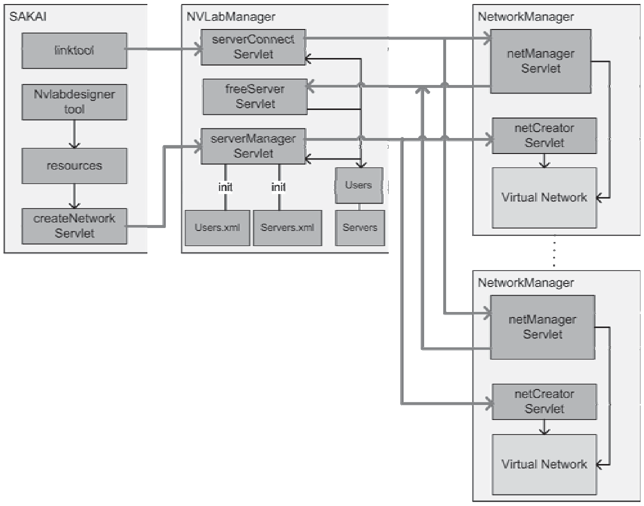

Figure 4. The new system structure

addressing concepts, the new tool has been configured and included in the course to introduce a simple exercise to the learners. The suggested exercise involves assigning the correct IP addresses to two computer machines which are connected to one switch and test the connectivity between them using the "ping" command. The original contents of the course provided the necessary background information on IP address structure and sub-net, and the student was asked to use the laboratory to apply what he/she has learnt.

The learner starts by drawing a network similar to the one shown in Figure 5 and then saves this network-diagram in the *resources* by selecting the proper option from *Nvlabdesigner* Applet's menu (save). Next, by clicking on the link *Create Network* the learner sends the diagram to *NVLabManeger* which will assign a free server to the user and redirect the diagram information to it.

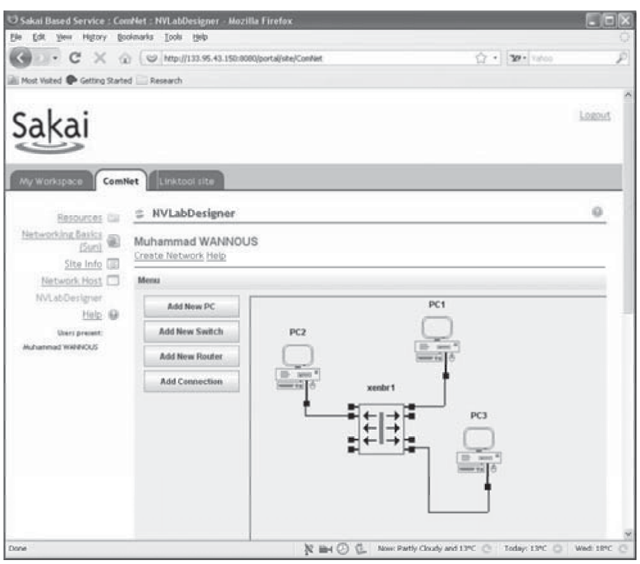

Figure 5. *NVLabDesigner* GUI

```
name = "PC1"
maxmem = 64
memory = 64
vcpus = 1
builder = "hvm"
kernel = "/usr/lib/xen/boot/hvmloader"
boot = "c"
pae = 1
acpi = 1
apic = 1
localtime = 0
on_poweroff = "restart"
on_reboot = "restart"
on_crash = "restart"
device_model = "/usr/lib/xen/bin/qemu-dm"
sdl = 0
vnc = 1
vncunused = 0
vnclisten = "xx.xx.xx.xx"
vncdisplay = "5"
vncpasswd = "********"
keymap = "en-us"
disk = [ "file:/var/lib/xen/images/PC1.img,hda,w", ]
vif = [ "mac=00:16:3e:78:d9:00,bridge=xenbr1,type=ioemu" ]
serial = "pty"
```

Figure 6. Sample VM configuration file

Upon receiving this diagram, *NetworkManager* will create a *Virtual Network* that corresponds to the diagram, start the machines included in it, prepare the necessary files for accessing the VMs' terminals, and send a confirmation to the learner side indicating success. The learner is then able to use Sakai *linktool,* renamed as *Network Host* in the course *Site,* to connect to management interface residing on the server he/she has been assigned. This interface will show a list of the VMs running on the server and provide links to their terminals.

For the current exercise, we selected Fedora Core 6 to be run inside the VMs. To complete the task, any two IP addresses belonging to the same subnet will work and the learner decides to use the private network address 192.168.0.x/24, then configures eth0 interface on both machines by entering the command:

```
ifconfig eth0 192.168.0.X netmask 255.255.255.0
```

where X is 1 in the first machine and 2 in the second. Finally, to check connectivity between the two machines the learner enters the command `ping 192.168.0.2` in the terminal of first machine to get the result as shown in Figure 9.

Having completed the basic task required in the exercise, the learner may wish to move on and configure a third machine then try checking connectivity among the three machines or try to make changes to the IP plan and see what happens. And when done with the network, the learner can go back and continue navigating through the other course-contents.

```
<HTML>
<HEAD>
<TITLE>
TightVNC desktop PC1
</TITLE>
</HEAD>
<BODY>
<APPLET CODE=VncViewer.class ARCHIVE=VncViewer.jar WIDTH=800
HEIGHT=632>
<PARAM name="port" value="5905">
</APPLET>
</BODY>
</HTML>
```

Figure 7. Sample html file for viewing a VM's terminal

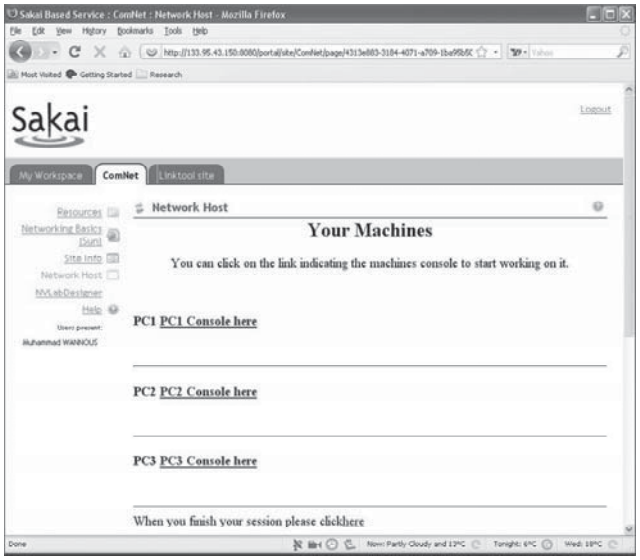

Figure 8. *netManager's* web-interface

V. Conclusions

In this paper, we presented a work-in-progress technical report that shows advancements in integrating a laboratory tool into the course context in Sakai LMS. The suggested system is based on NVLab which is a stand-alone web-based laboratory for *Computer Networks* online-courses. In the new system, part of the laboratory has been integrated as a new tool into Sakai, and the other part has been kept as a separate module since it requires managing a server-pool from which each learner is assigned one server to work on. New features that enable tracing the learners' progress and facilitate access to the workspace have been included.

The new system has been tested by introducing a simple exercise on basic IP addressing and connectivity check, and the learner was able to complete the exercise successfully.

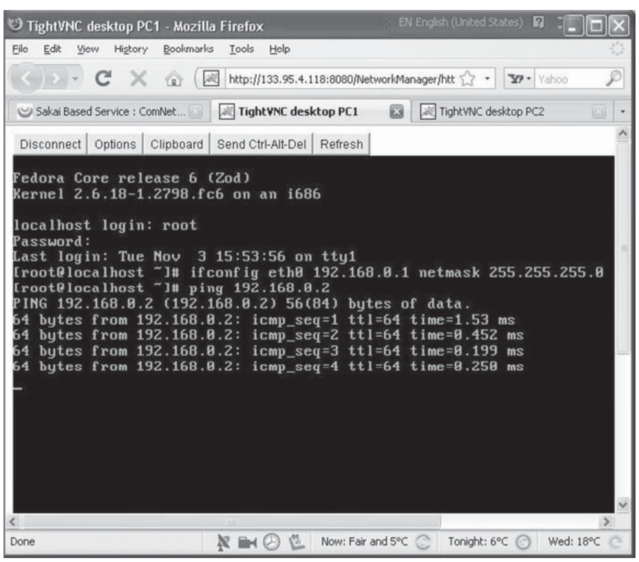

Figure 9. The VM terminal as shown in the learner's web browser

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Session 01E Area 1: Computer Supported Collaborative Learning - For use in projects

SUBA – An innovative pedagogical experience
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Encouraging Interaction and Status Awareness in Undergraduate Software Engineering Projects
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Durham University (United Kingdom); Newcaslte University (United Kingdom)

The use of agents to represent learners in role-play training
Mikami, Akane; Nakamura, Taichi; Takashima, Akio
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Game-based learning in technology management education
Günther, Markus; Kiesling, Elmar; Stummer, Christian
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SUBA – An innovative pedagogical experience

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***Abstract*— In this paper we will introduce the integrated projects implemented on several courses of the Electronics Engineering Bachelor and Master programs at IST with special emphasis on stimulate students' creativity and practice of implanting prototypes. The key hardware of these projects is a car model with controlled electric engine and sensors and actuators - SUBA.**

Keywords – learning experimentally; car models; component; ubiquitous learning.

I. INTRODUCTION

In 2003/2004 academic year started at IST (Instituto Superior Técnico), Technical University of Lisbon (UTL) a new studies program: a 5 years engineering graduation program on Electronics Engineering. In 2006/2007 its curricula was adapted to Bologna system: a first cycle with 3 years leading to a Bachelor degree; followed by a second cycle with 2 years leading to a Master degree. Accordingly, the first Master on Electronics Engineering had concluded their studies in summer 2008.

The program curricula [1] is 90% similar to curriculum followed by a student on Integrated Master (5 years program) on Electrical Engineering and Computers, also from IST, if he choose Electronics as the main area of specialization and Telecommunications or Computers as secondary area of specialization [2]. However, these programs are radically different on the pedagogical approach. It was introduced in the new degrees a strong experimental integrated component from the first through the last semester. Since the "numerus clausus" for Electrical Engineering and Computers is 215 and for Electronics Engineering is only 35, the available infrastructure (laboratories and teaching staff) enables the differentiation of the pedagogical approach on both programs. Also these two programs are lectured on different Campus with different physical infrastructures. The Integrated Master on Electrical Engineering and Computers is at the old Alameda Campus close to Lisbon centre and the Bachelors and Master Degrees on Electronics Engineering are at the new industry and research Campus at Tagus Park, Oeiras, a Lisbon suburb.

The Bachelor and Master Programs in Electronics Engineering are aimed to providing students with advanced training in a vast range of knowledge and stimulate their creative skills, focused on cutting-edge technologies in electronic components, equipment and systems on all its aspects and applications (telecommunications, control, informatics, energy, etc.). These professionals should be able to meet different needs ranging from engineering design to production and commercialization of electronic products with a view to speed up the technological development of the country. Since in the first years of the Bachelor program most of the courses are on mathematics and physics and few on electrical engineering are introductory, to motivate the students and illustrate basic concepts several integrated experiments on an innovative pedagogical experience were developed such as the SUBA project [3] that will be detailed on this paper.

The novelty of this project is the integrated experimental part of several courses and its key hardware. The name SUBA comes from the basic hardware used on these experiments: a Rally car model **Suba**ru Impreza WRX scale 1:10. The initials also stated in Portuguese "Be a good student" (*Seja Um Bom Aluno)*. SUBA gives to students, from the beginning of their studies, the opportunity to learn several basic courses doing design of systems with progressive and complementary complexity, in an integrated way, benefiting from knowledge acquired in successive courses: Physics, Chemical, Logical Systems, Control, Computer Architecture, etc.

Another pedagogical innovation was the creation of open integrated laboratories very well equipped with basic common equipment that is complemented every semester with specialized equipment required by the more advanced courses. . These laboratories are responsibly used, all the day, by the students in course projects and in their own projects without limitation.

II. OVERVIEW OF ELECTRONICS ENGINEERING PROGRAMS

In the Bachelor Curriculum (3 years, 180 ECTS – European Credit Transfer and Accumulation System), all courses (CU – curricular units) are given during a semester with 14 weeks of lecturers and 4 weeks of evaluation process: finalize and discuss projects and/or written examinations. The basic courses are 10: 6 courses on Mathematics, 3 on Physics and 1 on Chemistry, all located on the first two years. Additionally, on these two first years 4 courses on computers and informatics, and 4 on electrical engineering, 2 of them on electronics (devices and circuits) are lectured. In the last year 3 courses on electronics, 4 on different areas of electrical engineering and 1 on informatics are introduced and the curriculum is completed with 5 transversal courses like management and Technical Drawing and Geometrical Modelling.

In the Master Curriculum (2 years, 120 ECTS) besides the Master Thesis that is developed along the second year (12 ECTS on the first semester and 30 ECTS on the second) the students have to be approved in 4 compulsory electronics courses and 4 optional that must be at least 2 also from electronics but the 2 other can be one from any subject on electrical engineering and other from informatics or computer technology. The curriculum is completed with 3 transversal skill courses, one of them on management.

III. The SUBA Platform

The Subaru Impreza model was selected because it can be easily modified to include an aluminium chassis under the plastic cover to support added electronics for control. Figure 1 presents a photo of a model with two breadboards side by side and an ARM microprocessor development system mounted on the aluminium chassis.

Figure 1. Car model modified to include a breadboard (1) and a printed circuit (2) without the plastic cover (3).

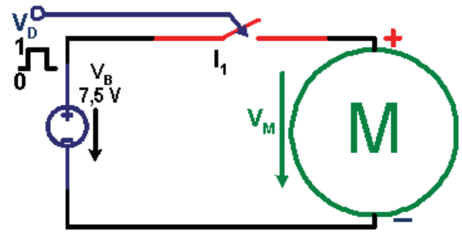
By using a reverse engineering process schematics of all the original model hardware is available for the students in the SUBA site. A special electronics board was designed with several facilities and interfaces for an ease connection of students' projects with the model electronics. SUBA has two electrical motors: one for traction and other for direction control.

The engines speeds are digitally controlled. Figure 2 presents the engine speed control basic system based on a pulse width modulation (PWM) of the engine bias. One of first student's projects is to understand and control the traction engine speed. A sequential logic machine is developed in order to simulate the operation of a mechanical gear box with several gears forward and one backward speed.

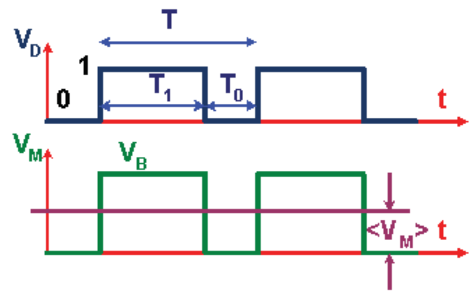
The second engine available on the model is used to control the steering movements: left and right.

In more detail are presented in figure 3 the both engines control circuits based on bipolar transistor technology DC biased by batteries (typically a 9.6 V nickel cadmium rechargeable battery).

Several sensors and actuators were added to the model namely a speed meter, a differential optical direction sensor, wheels angular speed meter and an ultra sonic obstacles sensor.



(a) DC engine power supply PWM controlled schematics



(b) Speed digital control V_D and respective supply voltage V_M

Figure 2. Car model speed control.

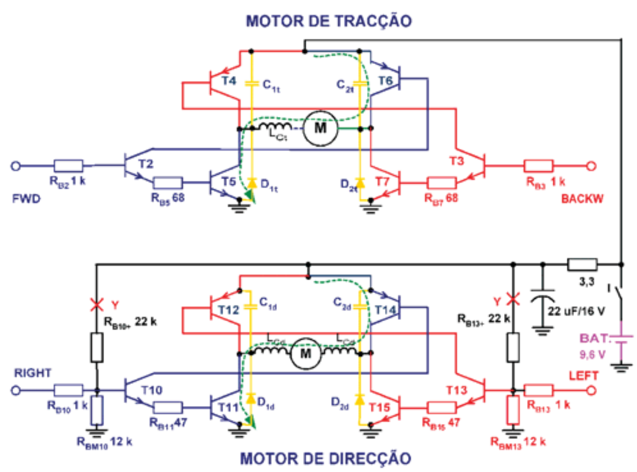


Figure 3. Car model traction and direction engines drivers.

One of the key parts of the SUBA experiments is the SUBAdrome: it is a ramp (figure 4) with 2.5 m length and 30 cm width used for several experiments (more than 20 experiments were developed for Physics course).

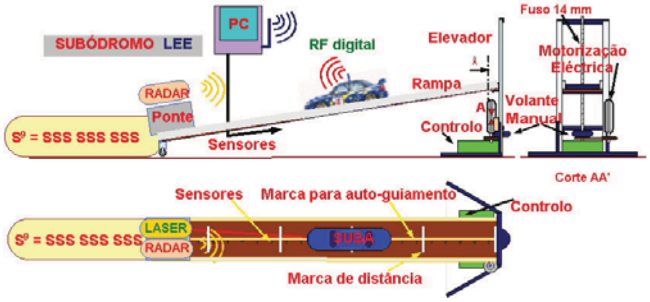


Figure 4. The SUBAdrome – ramp for experiments.

The SUBAdrome has several important features that will be following described and can be noticed on the figure 4.

The ramp slope can be changed by an electric elevator. Over a bridge is located an ultrasonic pulsed radar (30 kHz to 40 kHz signals) that allows to follow the SUBA model movements on the ramp.

The results of the telemetric system installed on board with a speed meter are transmitted via a digital radio system to a PC installed closed to the SUBAdrome. This, so called SUBAradio system has two transceivers, one connected to a PC serial port and the other is at the car model. The system is able to transmit digital data at 200 kbps on a RF carrier of 432 MHz in a range of 50 m in open space.

Also a Doppler system can be installed on the SUBAdrome: loudspeakers on the car model and an audio microphone installed on the SUBAdrome bridge allow the computer to measure the frequency shift of the sound.

Twenty five optical emission/reflection sensors are located on the ramp soil to detect the car position at any time.

All collected data is processed on a PC and allows verifying several physical kinetic laws and compare experiments with theory as it will be shown latter.

At the lower end of the SUBAdrome can be noticed the S^9 system developed to carefully hold the car and avoid any damage.

IV. Experiments

During the first semester of the first year, students have the first contact with SUBA: the SUBA Trophy. This experiment is on the mainframe of Digital Systems course.

SUBA Trophy is a creative competition among students to stimulate them on using hardware/software combination. They use simple TTL or CMOS logic components and the breadboard and/or FPGAs (Field Programmed Gate Arrays) to control the model.

Following, as an example, some of the Trophy goals are explained.

Implementation of two sequential machines: one simulating a sequential gear box with PWM signals as explained before; and a second one that controls a predefined series of movements using all gears and the right and left turn movements keeping the SUBA model always inside a predefined area of 6 m x 6 m. A seven segments display, located at the top of the car must show at any moment of the demonstration the used gear. Figure 5 presents a SUBA model totally prepared to compete on a SUBA Trophy.

Figure 5. SUBA model ready to compete on a SUBA Trophy with TTL ICs

On the first year, second semester, SUBA experiments are carried out on the mainframe of three courses: Mechanics and Waves, Computer Architecture and Data Structure and Algorithms.

On Mechanics and Waves the experiments are all processed at the above described SUBAdrome. Calculations of different rolling conditions are tested: different pavements and/or wheels materials (rubber, aluminium and Teflon), and ramp different angle. The up and down movement on the ramp for several speeds including free wheel skid is tested. The comparison with theoretical simulations is performed using the car model movement equations in different conditions. Also energy conversion potential – kinetics along the ramp and electrical-heat when the car is braking are experimentally verified. To break the car electromagnetically the engine is working as an electric generator that supplies resistive loads digitally configurable. This is the first students contact with energy recover. The car engine power supply is controlled by PWM as explained in the previous section. Its operation was already studied at Digital Systems course. The engine power is calculated for several duty cycles, i. e., power supplies or speeds. Several experiments guides are available on the SUBA website.

For basic studies on Mechanics the SUBAdrome is also used testing the movement of coaxial cylinders with different weights, dimensions and materials. Inside cylinder may be free or fixed with the external cylinder. Cylinder fall in the SUBAdrome converts potential energy in kinetic and or revolving energy. Using the 25 sensors available in the SUBAdrome the cylinders displacement can be easily followed. Figure 6 show a student using the SUBAdrome with a cylinder rolling down (a) and the generated signal on the passage of the cylinder on te SUBAdrome sensors (b). Each student prepares his own experience. All students read the SUBAdrome signal on their computers, equipped with data acquisition systems, and model the experience conditions.

(a)

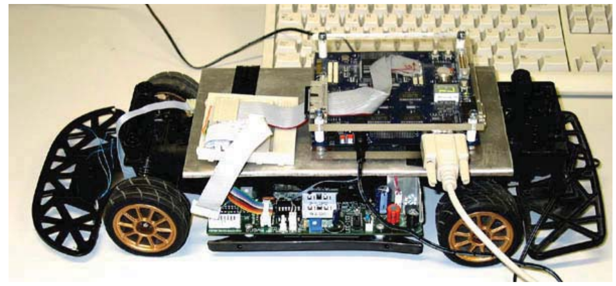
(b)

Figure 6. SUBAdrome used for basic mechanics experiments

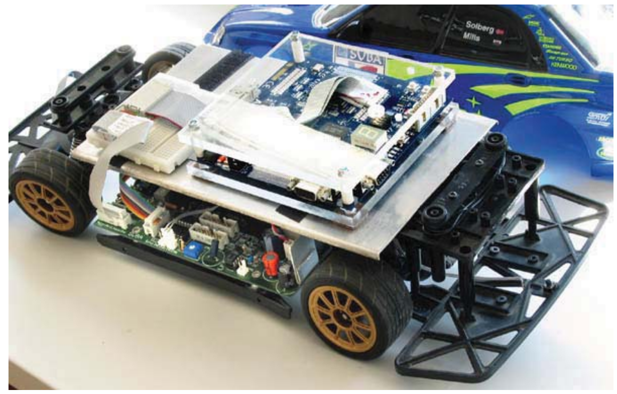
The basic Mechanics experiments can be easily implemented on secondary schools. They don't need all sophisticated and more expensive electronics associated with the study of the SUBA model movements like radio communications, 3D movements' sensors, engine PWM control and so on.

To increase the SUBA model performance, on the mainframe of the courses Computer Architecture and Data Structure and Algorithms, a 32 bit RISC microprocessor with ARM architecture was introduced.

The ARM algorithms are introduced in language C or Assembly that are studied on the courses on Basic Programming. The access to the ARM ports is implemented on the SUBA model by a connector with a flat cable that is clearly noticed on the fully armed model of Figure 7, firstly being programmed (a) and secondly ready for a more advanced SUBA Trophy (b).



(a)



(b)

Figure 7. SUBA model ready to compete on a SUBA Trophy with a RISC microprocessor

The new generation of the Subaru Impreza model direction is not only controlled by two steps L/R or straight (ahead) as in the previous ones. Accordingly, now a progressive control servo system with automatic steer alignment developed by a student on the 3rd year was implemented with a system based on a microcontroller PIC. Figure 8 presents the schematics of the SUBA model direction which has trapezoidal bars controlled by an electric engine.

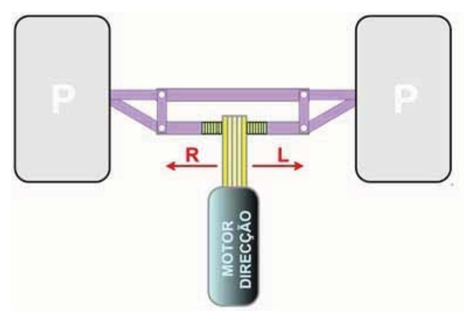


Figure 8. SUBA model trapezoidal bars direction

With this new version a SUBA Trophy where the main challenge was to program the SUBA model to follow a scaled version of the Estoril motor racing track with some short connection (figure 9) was implemented. The Estoril motor racing track is only a few kilometres from IST Tagus Park Campus.

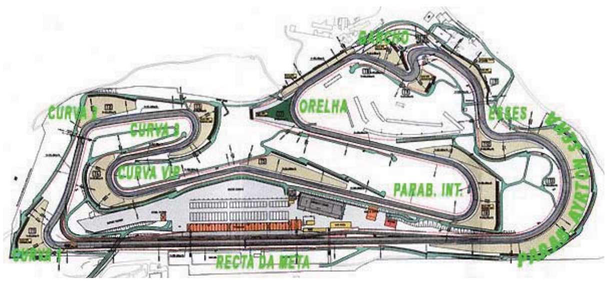


Figure 9. Racing track for advanced SUBA Trophy

V. CONCLUSIONS

Since the first year of the implementation of the new graduation program on Electronics Engineering a new integrated experimental platform has been developed. It has at least two main objectives: to allow experiments based on skills acquired in many different courses from different scientific areas to show their interdependence and the need of a 3rd century electronics engineer to have acknowledgments on a broad area of subjects; to motivate the students to develop and use electronic hardware, since the first semesters most of the courses are on mathematics and physics. The SUBA project trough their Trophies where working on a team is needed is also a good vehicle to help the engineering students loosing afraid of doing hardware, test their ideas and develop their team working skills.

Due to the SUBA experience on the first years the students are more motivated to study in detail other courses like those related to control and electronic systems to fully understand the SUBA performance on experiments of previous courses. Also the students are willing to have projects and develop prototypes on advanced Master (2nd cycle) courses.

The SUBA platform is dynamic and new features are being added. New sensors are being developed on Master courses projects. On the mainframe of one Master Thesis a SUBA car with a hydrogen cell (SUBAH) was implemented.

Also the SUBA project is used to support the Electronics Engineering program objectives presentation in secondary schools where potential future students are now studying, not only with on site demonstration but also thru the SUBA website. Two simple versions of the SUBA are being developed by students' initiative, not included in any course, to be used on the secondary schools and exhibitions, showing their own interest on the SUBA project.

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Encouraging Interaction and Status Awareness in Undergraduate Software Engineering Projects

The Role of Social Networking Services

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Abstract— **As part of the CETL ALiC initiative (Centre of Excellence in Teaching and Learning: Active Learning in Computing), undergraduate computing science students at Newcastle and Durham universities participate in a year long, inter-institutional group programming assignment. Teams of students act as "virtual companies" and collaborate cross-site to develop software products for real-world industrial clients. This paper investigates the emergence and autonomous adoption of social networking technologies in our students' communication strategies during the project, and explores the role that "status awareness" (knowledge of the current activities of one's team mates) had on the outcome of that collaboration. We also present and discuss the findings of a recent trial of CommonGround, an application created to harness our students' pre-existing engagement with social networking technologies such as Facebook.**

Keywords: computer science education; social factors; facebook; collaborative work; professional communication; programming; technology

I. Introduction

Active Learning in Computing is the first Centre for Excellence in Teaching and Learning (CETL) for Computing Science in England [1]. The five year initiative is funded by the Higher Education Funding Council for England (HEFCE) and is a collaborative effort between a consortium of North East UK universities: Durham University (who lead the project), Newcastle University, Leeds Metropolitan University, and the University of Leeds. Running since 2005, the CETL aims to better prepare students for the realities of working in their chosen professions by aligning their learning experiences with those sought by today's software engineering industry [2, 3]. In particular, it addresses the distributed working practices of many professional software development companies and, in turn, our need as educators to equip students with the skills required to work in this competitive environment.

As part of this project, we have extended the traditional undergraduate Software Engineering curriculum taught at both Newcastle and Durham universities to include a year long, inter-institutional team programming exercise, in emulation of modern industrial practice. Teams of students act as "virtual companies" and collaborate cross-site to develop software products for real-world corporate clients (projects differ from year to year; examples include a supply chain logistics program and a mobile GPS graphing application [4]). From a pedagogical perspective, this approach places a far greater emphasis on group collaboration and professional skill development than is usually adopted by university computing departments [5], despite research that indicates a number of significant educational benefits [6]. It also encourages greater engagement with the discipline, increases technical and transferable skill sets, and ultimately provides students with a genuine insight into the challenges faced by companies competing in a global market.

In this paper, we provide an overview of the computer-mediated communication (CMC) technologies selected by students for use on-project, and the resultant issues encountered. In particular, we discuss the adoption of the social networking site Facebook as part of our students' local and cross-site group collaboration strategies, and report on a pilot study of *CommonGround*, a Web 2.0 application developed by us to harness and monitor this engagement.

II. Team Infrastructure

In the four years since 2005 that the group programming assignment has taken place, 556 level 2 students have participated. These students are enrolled on a number of computing programmes including single honours Computing Science, Software Engineering, Information Systems, and Natural Sciences, with the Software Engineering module being common to all. During the exercise, a number of "companies" are formed, each comprising a team from Newcastle and Durham (containing on average between 6-8 and 4-6 students respectively). Membership of each team is chosen based on performance and achievement in programming classes during level 1. This is to ensure a fair distribution of programming skills throughout the teams and to give all students an equal chance of delivering a satisfactory end product.

The cross-site teams then have one full academic year to complete the project and are given a set of deadlines spanning two semesters for their major deliverables. Each team must define their own organisational structures and software design methodologies, and project-manage all stages of the development process (from encapsulating requirements through to the implementation, integration and testing of their final systems). Assessment, including the students' ability to work well as a team, takes place in a number of different ways, including group presentations, documentation delivery, live demonstrations, the completion of individual reflective reports, and observations during meetings (by members of staff who act as team-monitors).

The activity has, on the whole, been very well received by students, as the following excerpt from a team's end-of-project report demonstrates:

> *"We feel the project was very worthwhile. Our various accomplishments and failures now seem unimportant compared to the knowledge and experience gained. We have not only learned a lot of programming and technical skills but have gained some great life experiences in team working and project management which we will carry with us into any future work."*

However, despite several iterations of this cross-site collaboration, we still find that encouraging and supporting communication between students is one of the most challenging aspects of our work.

III. Communication Strategies

In the early stages of the project, to stimulate and support team collaboration, we provided students with a number of CMC technologies. These tools, representative of the techniques used in industry, ranged from fully equipped Skype-enabled video-conferencing suites to virtual learning environments, file repositories, forums and wikis. However, student feedback (gathered from questionnaires, end-of-project reports and focus groups) indicated substantial resistance to the use of these facilities, attributable mainly to the sheer variety of technologies on offer (see [7] for a full discussion). In particular, students were unaware of the relative benefits of each technology and unfamiliar with their use; as a result they tried to use them all rather than commit to any specific subset.

Feedback also showed that students found it particularly difficult to determine, even after face-to-face discussions, what their teammates were working on at any one time (see Table I). This was particularly evident cross-site, where less than a quarter of students surveyed were able to keep track of the activities of teammates. Almost inevitably, this would lead to duplication of work and increased frustration within the teams.

TABLE I. Student Status Awareness, 2008-2009

Can you tell at any one time what your teammates are working on?				
	Newcastle Uni. (N=61)		***Durham Uni. (N=22)***	
	Locally	*Cross-site*	*Locally*	*Cross-site*
Yes	41	13	16	5
No	20	48	6	17

Paradoxically, despite representing the CMC tool of choice for students, email frequently exacerbated team communication problems; it presented the longest delay in average response times. Furthermore, reports from team monitors suggest that students were reluctant – at least in the early stages of the project – to exchange personal contact information (e.g. mobile telephone numbers, instant-messenger IDs, etc.) until they had become better acquainted.

To better highlight these issues, we now include excerpts from student feedback reports discussing the communication problems encountered on-project, emphasising the difficulties experienced both locally and cross-site:

> *"We could not meet ad hoc to discuss progress. This meant we had no way of monitoring or checking the progress at the other site between formal weekly meetings, except via email – and these messages did not contain enough detail about what had been done."*

> *"The bigger the team, the more people that we needed to keep in the loop, which was a problem because each student had their own working patterns. Some did not read their email every day and some decisions needed a quick response from key members in the team. This meant that decisions were often delayed. "*

> *"Brief comments in the repositories for code and documents were not detailed enough and we were often unsure who was working on which module or document at any one time. This often led to the repetition of work."*

> *"It was often easy to misinterpret the intent and tone of an email or IM message and this led to conflict in the group. Some of us felt that being asked constantly about progress meant that our colleagues did not trust that we were working on our assigned tasks."*

Although the CMC technologies provided by us did play a role in supporting our students' collaborative efforts, when the facilities consistently failed to meet expectations, teams ultimately abandoned them in favour of more convenient, proven technologies. The social networking site Facebook is perhaps the best example of this; it was not introduced into the project by us, but was autonomously adopted by the students themselves.

IV. Creating a Common Ground

A. Social Networking

Social networking sites such as Facebook, Bebo, MySpace and LinkedIn have experienced unprecedented growth in popularity and membership in recent years [8]. Fuelled by considerable media attention, this proliferation has exposed the latent sociability of the internet – people are now accustomed to thinking of the online world as an interactive, social space [9]. Of course, social interaction and community organisation on the web is nothing new [10], but the scale at which people are adopting and actively using the technology is; today, mainstream social networking sites arguably represent one of the most important CMC mediums for individuals, organisations and researchers alike.

Since the release of SixDegrees.com in 1997, more popular (and far more successful) services have appeared that allow users to represent themselves and their social networks online. These sites are all based on the common principle of connecting and building online communities, but offer myriad variations around that shared theme. Facebook, for instance, connects people from similar educational backgrounds, MySpace connects people with similar social pursuits, and LinkedIn connects people with similar business and employment interests. Following this trend, other mainstream online services such as YouTube and Flickr (collectively referred to as social *media* sites) have also started offering integrated social networking facilities to enhance their core functionalities.

For illustrative purposes, we include in Table II questionnaire results from our investigation into student uses of CMC technologies during the 2008/2009 academic year (at the end of semester 1). 12 companies participated in the survey, represented by 61 students from Newcastle University and 22 from Durham. As can be seen, Facebook was used locally by over 70% of the students surveyed, and over 40% cross-site.

TABLE II. STUDENT CMC TECHNOLOGY USE, 2008-2009

Which forms of CMC do you use to interact with teammates?				
	Newcastle Uni. (N=61)		***Durham Uni. (N=22)***	
	Locally	*Cross-site*	*Locally*	*Cross-site*
Mobile Phone	44	18	14	17
Skype	13	41	18	33
Email	59	52	20	22
Mobile Text	53	14	9	17
Instant Message	39	19	10	13
Facebook	39	27	8	18
NESS[a]	17	2	0	1
Wiki	29	24	5	7
Forum	10	11	2	4
Other	2	2	2	2

a. NESS is a web-based Virtual Learning Environment developed by Newcastle University

B. *Facebook*

Launched in 2004, the Facebook website is based on the concept of a US-style "year book", where members create publicly-viewable, self-descriptive profiles to describe themselves and their interests [11] (accompanied by a representative, and often flattering, headshot photograph). Members are then invited to articulate their social graph by connecting to other profiles, or 'friends', and in doing so build networks of affiliations based around common interests or shared circumstances (e.g. home town, place of work, political views, recreational interests, etc.). Mutual friends (i.e. connections that have been approved by both parties) are thus able to view one another's profile information, share photos, songs, videos, discussions, and "most other forms of expression" [12]. This process of co-constructing social networks of connections on Facebook, informally referred to as "friending", represents an integral piece of an individual's online self-presentation [9].

Unique to Facebook, members tend to present their identifying information openly and truthfully (e.g. the use of real names rather than pseudonyms or aliases), seemingly undeterred by privacy issues [13]. As reasoned by Grossman [14], "identity is not a performance or a toy on Facebook; it is a fixed and orderly fact." Significantly, the ease by which this information can be accessed greatly lowers the transaction costs associated with social searching; that is, finding and connecting to one's known acquaintances [15]. Again, this act of mirroring one's offline relationships online is peculiar to the Facebook community, contradicting the longstanding assumption that CMC relationships predominantly move in an online to offline direction [16].

C. *Social Capital*

For many of our students, Facebook is an integral part of their daily routine; beyond micro-managing their social life, it offers an inherent capacity for generating social capital [17] (i.e. the resources accumulated through relationships with other people). As supporting research into the use of social networking sites in academic and professional contexts shows, Facebook can help crystallise relationships that might otherwise remain temporary or ephemeral [17]. In the business world, particularly where graduate employees are concerned, these informal connections have been shown to return strong payoffs in terms of social support and access to expertise and organisational knowledge [15, 17]. Indeed, these networks of professional affiliations allow individuals to better maintain and strengthen relationships with colleagues [18], and can often facilitate *on-task* interaction (as many productive discussions in team-working environments occur during chance, informal encounters [19]).

Perhaps more importantly, Facebook also encourages inclusion and participation from students with low self-esteem, who present difficulties forming and maintaining offline relationships with their colleagues [17]. The value of social interaction cannot be underestimated when trying to build trust and empathy between distributed team members [20]. Furthermore, as shown by Selwyn [21], the service can also act as an important site for the informal, cultural learning of being a student, with online interactions allowing roles to be learnt, values understood and identities shaped.

D. *CommonGround*

Of particular significance to this study, Facebook offers unparalleled access to the personal information and activities of one's friends and colleagues, in addition to supporting numerous synchronous and asynchronous communication affordances. To exploit these features and further enhance the user experience, Facebook opened its platform to software developers in 2007. This allowed third-party internet applications and web-based services to be seamlessly integrated into the site, taking advantage of the social connections of its users. The release of the Facebook application framework has received notable media coverage and user uptake; as of October 2009 there are more than 210 million users of 350 thousand third-party applications on the platform [23].

Endeavouring to embed Facebook's collaborative and "status awareness" features into our cross-site activity, we have developed our own *proof-of-concept* RIA (rich internet application) called CommonGround, designed to run on the Facebook platform (see Figure 1; profile images have been obscured and fictitious names used to maintain anonymity). The pedagogic motivation behind this work is to foster greater team interaction, trust [20] and self-disclosure [22] by filling the communication void that arises between students' face-to-face meetings [16]. By reducing the geographic and temporal barriers to interaction and community formation, team members will become increasingly aware of each others' skills, personalities, work rhythms and needs – both online and off – within a pre-existing, persistent, convenient infrastructure.

Figure 1. CommonGround running on Facebook

Developed in Adobe Flex, the application provides a standards-based interactive experience to the user, utilising and extending the inherent communication and social awareness affordances of the Facebook platform. Employing the new Adobe Flash Collaboration Service, the application is able to offer a number of facilities to the student: better team interaction and familiarity (via profile exploration and informal encounters), increased status awareness (via status updates), and greater project planning potential both locally and cross-site (via a simple company-wide task list).

CommonGround's status awareness features represent an area of particular interest to us. As touched upon earlier, the application allows users to publish a simple and succinct one-line textual "status" describing their daily work activities and opinions for teammates to view and comment upon. Of note, during our study it became apparent that students did not wish to have their main Facebook status altered – that is, their primary profile status that is available to their entire friend network – and so a separate, project-specific status is maintained local to the CommonGround application (and each individual company).

To stimulate informal interaction via productive chance encounters [19], and to enable basic online awareness between students, we have also created a "virtual meeting room" that displays presently connected users and their institutional affiliations. We have employed a familiar visual setting; one that is analogous to the students' real-world meeting environment (i.e. an illustrated reproduction of a traditional face-to-face meeting room). Profile images represent users and help put a face to cross-site teammates, many of whom the students may never meet in person. Basic name and team-role details can be accessed by rolling over a profile image, and then clicked upon to view that teammate's full Facebook profile (often including detailed contact information).

A simple chat facility is also available for synchronous discussion with online teammates, supplemented by the integrated and private one-to-one Facebook chat feature (discussion boards, provided by the Facebook service and set-up by us, are also available for asynchronous interaction). CommonGround also offers students a basic scheduling facility providing a team-wide overview of pending project tasks, responsibilities, due dates and progress percentages. Presented in-line, this schedule can be readily viewed and discussed, with roles and timescales collaboratively decided upon. We have also integrated our virtual learning environment NESS (Newcastle E-learning Support System) into Facebook. Accessible via CommonGround, it allows students to retrieve course timetables, share files, submit deliverables, and receive marks and feedback.

Of note, students had initial reservations with regards to using Facebook for the purposes of the project. As one would expect given the recreational use of Facebook and peoples' informal expectations of the service [24], students were particularly reluctant to be "forced" to add their teammates as friends on the service, especially with respect to their cross-site colleagues with whom they were less acquainted. However, our students' privacy is respected by CommonGround and teammates do not need to be "friends" in order to collaborate via the application. Once a company account has been created, members can simply join that group in order to participate; use of the application does not interfere with any other activity on Facebook.

V. Findings

A preliminary pilot study of the CommonGround application was performed during the 2008/2009 academic year. Four companies were invited to use the application – both locally and cross-site – during the final 8 weeks of the cross-site project (when companies typically implement their final systems). A total of 38 students from Newcastle and 24 from Durham took part. Each team reported they had already used Facebook for communication socially with their teammates, but only locally. To form a picture of the students' opinions of the CommonGround application, we interviewed participating teams and administered a second series of surveys during the final week of the project. A 100% response rate was observed.

TABLE III. Average Daily Activity on CommonGround

Companies 2, 3, 4 and 5	*Newcastle N=38*	*Durham N=24*
Impressions (i.e. application loads)	48	11
Chat Messages	33	18
Status Updates	6	3
Schedule Additions/Updates	1	1

Initial results are encouraging, supported by activity logs showing positive, heavy use of the application (see Table III). Team members, on average, accessed CommonGround more than once each day during the trial, if only to update their own status and view the activities of others. When regarded alongside the high levels of chat recorded, a considerable number of chance encounters were found (i.e. ad-hoc informal meetings with two or more team members). For example, Figure 2 demonstrates a three day single-company snapshot of student activity. Each connecting edge represents simultaneous access to the application (i.e. a chance encounter), with position (i.e. degree centrality) in the network determined by the amount of interaction which occurred during each encounter. Of note, detailed content analysis of the chat logs to determine the "on-task" nature of these interactions is currently underway and will be presented in a future work.

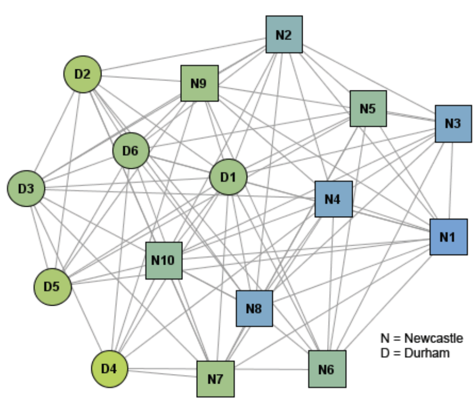

Figure 2. Network diagram of chance encounters (week 2, company 4)

Encouragingly, students in interview reported using CommonGround and Facebook as a "one-stop-shop" to contact and collaborate with teammates. As shown in Table IV, survey data also indicated that they were comfortable using Facebook on-project and integrated CommonGround into their working practices with little resistance (in stark contrast to technologies mandated by us). Indeed, these results indicate that students were significantly better able to maintain awareness of their teammates' activities when using CommonGround, with an increase in confidence of approximately 16% locally and 51% cross-site. The combined communication affordances of CommonGround and Facebook, in addition to readily accessible profile contact information, meant that students could get in touch with colleagues quickly, with standard email utilised only for less pressing matters. Of particular importance, all participants reported they felt "part of a team."

Interestingly, results from this study also show that a lot of the CMC facilities offered by CommonGround and Facebook were already provided by us in other applications (such as messaging and chat), but which the students chose not to use. The fact that this functionality was centralised on Facebook seems to have greatly influenced its adoption and use. Even email, which often tends to dominate students' local and cross-site communication strategies, appears threatened somewhat by the embedded CMC affordances of Facebook. Indeed, this finding is supported by reports of social networking message traffic overtaking that of web-based email [25]. Students feel certain that, even if teammates do not answer their mobile phone or read their email, they will eventually log on to Facebook and feel compelled to respond.

TABLE IV. Student Opinion of CommonGround

	Newcastle Uni. (N=36)		*Durham Uni. (N=24)*	
	Locally	*Cross-site*	*Locally*	*Cross-site*
Using CommonGround, were you *confident* that you could tell at any one time what your teammates were working on?				
Yes	31	25	19	19
No	2	3	0	3
Were you comfortable interacting with teammates on Facebook?				
Yes	33	28	20	17
No	2	3	2	4
Did you ever seek to learn more about a teammate via their profile?				
Yes	26	27	14	19
No	6	2	5	2
Did interacting on Facebook help your team communications?				
Yes	32	28	16	15
No	0	6	3	7

Note: 2 students left from Newcastle during the activity; "don't know" responses have been omitted

Of note, students were more inclined to formally report team communications via Facebook once they realised "it was okay to do so". Feedback shows they didn't initially perceive social networking sites as an acceptable form of professional communication, despite awareness of large corporate networks on the service. This finding is further highlighted by teams' end-of-project reports, which made only anecdotal reference to the trial use of Facebook and CommonGround for formal communication, despite the majority of participants reporting that it had helped communications.

VI. Discussion and Future Work

In the four years that we have participated in the cross-site project described in this paper, we have gained significant insights into distributed team collaboration and the areas that cause most concern to students. Some of these areas, such as assessment, have been able to improve year-on-year. However, despite our best efforts, both local and cross-site communication issues have presented much more of a challenge. As we have shown, the sheer variety of unfamiliar CMC technologies provided by us has arguably undermined our students' communication strategies, exacerbating the very problem that we were trying to solve.

More and more, however, our students are leading the way for us by autonomously incorporating freely available social networking technologies into their informal communication strategies, fulfilling their group collaboration needs and mitigating the shortcomings of the CMC facilities provided by us. Facebook in particular has emerged as one of their primary collaborative tools for both informal and on-task interaction; it was convenient, familiar, and already in frequent use.

The CommonGround tool described in this work was developed to transparently harness this pre-existing engagement with Facebook. It is a *proof-of-concept* application and, although it has received only limited use, our initial results and feedback from students have proven extremely encouraging. From a collaborative standpoint, CommonGround offers a means to foster group interaction and community-building by providing a centralised application through which students can interact and explore the personal profiles and work patterns of their team mates. By creating a persistent environment that interacts with and leverages the power of existing social networks, team members are able to better maintain their interactive cohesiveness, team awareness and project planning potential beyond face-to-face meetings. The application has helped reduce the barriers to both local and cross-site interaction and team building, and aided somewhat in the inclusion of more "peripheral" students.

It is our intention to further examine how social networks are formed and developed in this environment, and to evaluate the extent to which the added sociability, status awareness and planning facilities affect student motivation and social capital. To this end, a second, more comprehensive version of CommonGround is under development and is being trialled in the current academic year (using local and international cross-site teams, divided into experimental and control groups to allow for a more detailed comparison and exploration of the impact of CommonGround). A further trial of the software in an industrial setting is also underway, and will be reported on in a future work.

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The use of agents to represent learners in role-play training

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Abstract— **This paper proposes the use of agents to involve learners in supporting online group work for the study of project management.**

Role-play training may be an appropriate tool for universities to use as an efficient alternative to on-the-job training (OJT) for project management education. However, we have found that because of the way that role-play exercises using an on-line group work training system in the project management course have operated, students have not been able to share the required information adequately with other students.

In order to investigate the effectiveness of using an agent in role-play training, we have developed a role-play scenario so as to practice with agents. The results of analyzing the behavioral track record of each learner in a role-play exercise with agents are discussed. The results of a questionnaire survey taken among students who participated in a role-play exercise with agents indicate that the use of role-plays will enable them to learn human-related skills such as communication, leadership, and team building.

Keywords-component; Project management education; Agent; Role-play training

I. Introduction

The IT industry in Japan has required higher education institutions such as universities to provide project management education [1]. Role-play training could form an appropriate tool for universities as an efficient alternative to on-the-job training (OJT) for project management education [2].

Since 2007 we have been developing an online group work training system named PROMASTER (Project Management Skills Training Environment) to increase the learning opportunities when studying project management using role-play training and to achieve profile-based education (PBE), which takes account of the progress in study of each individual student[3]-[5].

However, we have found that because of the way that the role-play exercises using PROMASTER in the project management course operated, students have not been able to share the required information adequately with other students. In addition, a lack of understanding of the stakeholders' roles assigned to learners has meant that students have not really been able to fully appreciate the project management scenario that they have been role-playing. Accordingly some students may not be able to acquire the expected skills for project management.

In order to cope with this problem, it is desirable that a team performing a role-play exercise has at least one participant who can play the role of a mentor. This person should be an experienced project manager. However, it is not realistic to expect an experienced person to assist in leading a role-play exercise as a team member. Instead of having such a person, a software agent system, which implements the advanced professional skills of project management, may be able to act as a mentor in a role-play.

In order to realize a sophisticated agent, a Non-Player Character (NPC)-based system which can estimate the appropriate behavior of an NPC assigned to a stakeholder role to maximize its profit and generate alternative scenarios should be developed [6]-[10]. NPCs act in a role-play scenario using an outline description of a procedure for project management as stakeholders and can interact extemporarily with learners [11].

In our research, it is planned that the development of an agent system based on the general idea of an NPC will proceed on a step-by-step basis, as described by the following four stages: (1) an agent provides information which a learner needs to play a role; (2) an agent lets learners know the information needed for decision-making and encourages them to acquire information, and ensure information sharing; (3) an agent evaluates alternatives for decision-making by learners; (4) an agent proposes alternatives for decision-making [12].

This paper focuses on the first stage and discusses the results of analyzing the behavioral track record of each learner in a role-play exercise involving an agent, and the results of a questionnaire survey taken among students who participated in a role-play exercise. In section II, the expected advantages due to employing an agent in a role-play are described, along with a way of implementing such an agent. An experiment to assess and demonstrate the effectiveness of using an agent is described in section III. In section IV, we discuss the results of the experiment and future work, while section V provides a summary of our research.

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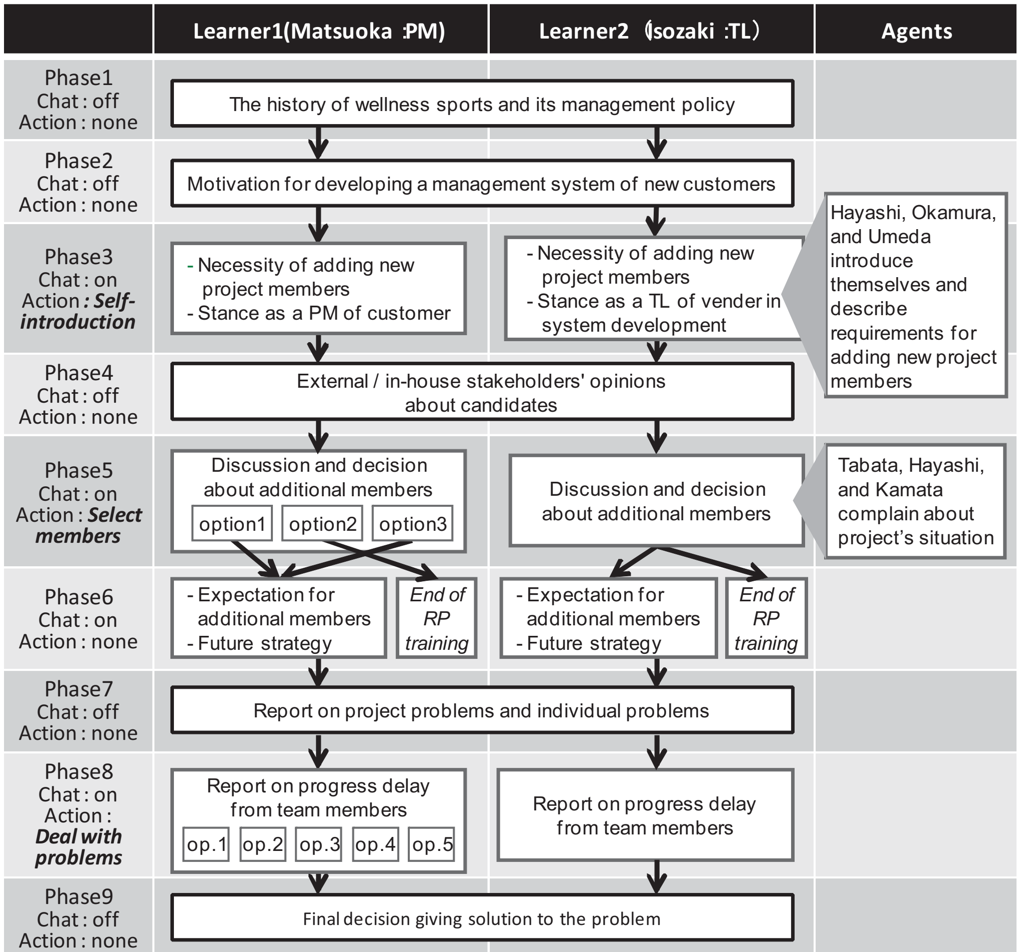

Figure 2. The structure of the team building scenario

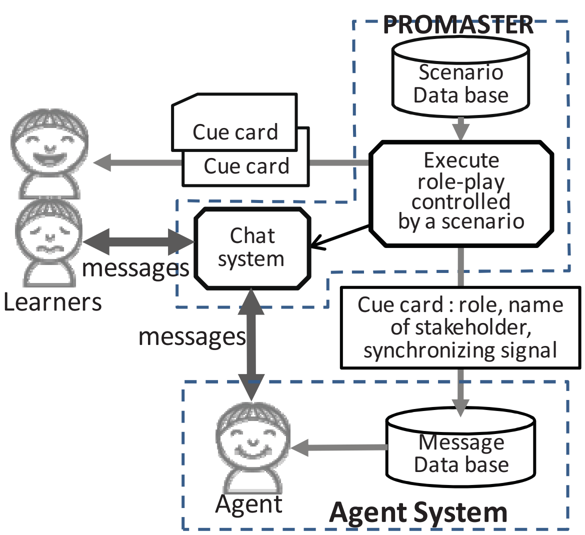

Figure 1. Role-play training environment with an agent

II. AN AGENT FOR ROLE-PLAY TRAINING

A. Role-play training environment with an agent system

Figure 1 shows the cooperation between the role-play training environment using PROMASTER and the agent system. PROMASTER provides information about a role which the agent will play and the contents of the next cue card, in accordance with the timing described in the role-play scenario for the agent. Two learners in the role-play have different priorities and exchange opinions through chat system in order to make a decision about the issue resolution in a virtual project with an agent who takes the place of one of the stakeholders, perhaps as an NPC and may be a mentor-agent advising. Two learners and the agent make effort to arrive at a win-win situation. Then the agent responds with appropriate opinions or comments to messages sent from PROMASTER to a chat system. The information retrieved from the message database in the agent system is displayed on the screen of a learner computer through a chat system.

B. A role-play training scenario using an agent

The role-play scenario used for practice with agents concerns building a team before starting a system development project. Two learners play the roles of the team leader of a system integration company and the project manager of a customer company, respectively. The task the two learners should practice is to select the appropriate members of the project in a situation where there is a conflict of interest between two stakeholders, the project manager of the customer company and the leader of the system integration company. The two learners exchange information provided by cue cards. The structure of the scenario is shown in Figure 2. In this scenario the agents take roles of other stakeholders and give different advice individually to the two learners.

The role-play exercise advances step by step with the actions of the two learners synchronized, and consists of nine steps. This scenario also has an undesirable path. If the project manager makes a decision which would result in a violation of information leak, the two learners are disqualified from further participation.

In each step the agent speaks first, before the two learners exchange opinions. The first talk by the agent in the role-play exercise seeks to make sure that the learners understand their roles and urges them to exchange the information needed to provide a solution.

The principles of designing a role-play scenario in which an agent appears are four in number, as follows.

(1) The agent must clearly present the same information to both learners through a chat session.

(2) The two learners exchange information provided by cue cards and the role-play exercise progresses.

(3) A chat medium should be used as a convenient way of exchanging information.

(4) The two learners analyze the information shared, exchange opinions, and make a decision on how to build the project team for system development. The attributes of an agent appearing in the role-ply scenario are shown in Table 1. These attributes are categorized into three types: Basic attribute of an agent; Factors influencing the agent's behavior; and Control information required by PROMASTER. If the agent takes the role of Project manager, it is acting alongside the learner.

TABLE I. Attribute Information for an Agent Appearing in a Role-play Scenario

	type	Attribute name	Content
1	Basic attributes of an agent	Name	Name of stakeholder: e.g. Mikami
2		Title	Occupation and title: e.g. Project manager and director
3		Affiliation	Name of the organization/department to which the stakeholder belongs: e.g. TUT/Planning department
4	Factors influencing the agent's behavior	Interest	Interest of a stakeholder
5		Sense of value	The most urgent and crucial thing for a stakeholder
6		Criterion for judgment	An important factor a stakeholder has to keep in mind when a decision is made
7		Character	Characteristics of a stakeholder: e.g. strong, strict, conscientious, bureaucratic
8	Control information required by PROMASTER	Action	The action expected by the agent
9		Timing	Time at which an agent should speak in a chat session
10		Phase number	Number of role-play step
11		Cue card number	Unique number of a cue card

TABLE II. ROLE-PLAY EXERCISE PARTICIPANTS AND ACTIVITY

Group No.	Learner No.	Role of a learner (Experience of role-play tarining)	No. of messages exchanged		Total no. of characters in messages		No. of times learners referred to cue cards	Duration of RP (mm:ss)
			sent	respond	sent	respond		
1	1	PM *1 (inexperienced)	6	1	427	16	10	40:24
	2	learder *2 (inexperienced)	5	2	241	23	0	
2	3	PM (experienced)	6	2	258	40	5	39:34
	4	learder (inexperienced)	6	5	309	66	6	
3	5	PM (experienced)	6	3	307	67	11	32:28
	6	learder (inexperienced)	3	3	186	56	13	
4	7	PM (experienced)	4	2	420	53	5	36:27
	8	learder (experienced)	4	2	480	58	1	
5	9*3	PM (experienced)	16	11	1116	215	26	103:49
	10	learder (inexperienced)	17	12	1880	137	11	

*1 PM, a Project Manager is working in the customer company, named Wellness Sports. The name of the PM is Matsuoka.
*2 A Leader is working in the vendor company. The name of the leader is Isozaki.
*3 This student had experienced the earlier version of the same role-play scenario without an agent.

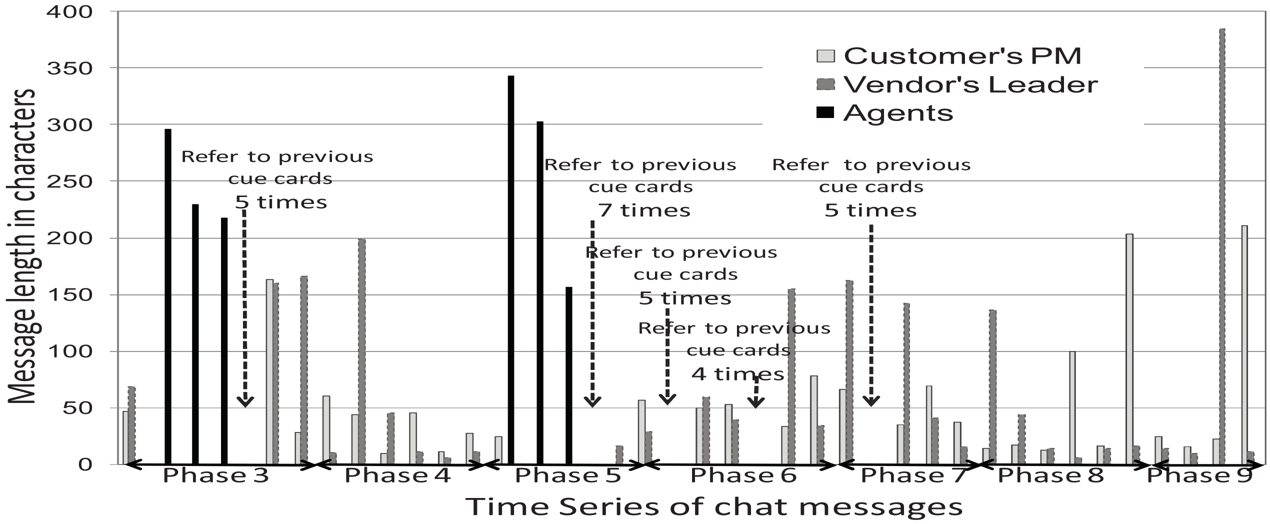

Figure 4 An example of the behavioral track record presenting the time series of chat messages of Group 5

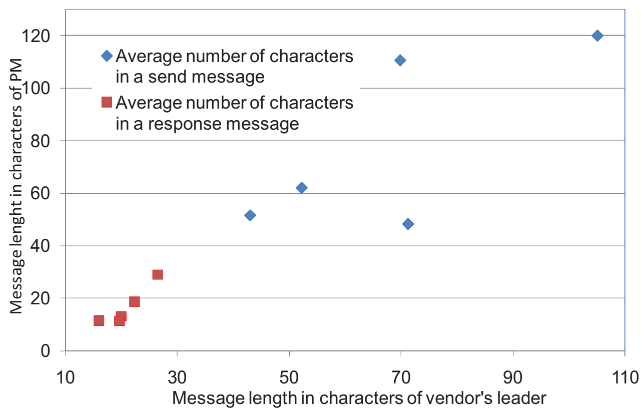

Figure 3 Relation between average length of messages (in characters) of the two participants for each group

III. EXPERIMENT USING A ROLE-PLAY EXERCISE

Ten students took part in the experiment. They were eight fourth-year undergraduate students, and a 1st-year and a 2nd-year master's degree students at the School of Computer Science, Tokyo University of Technology. Five students had previously experienced role-play exercises using PROMASTER on at least one previous occasion. Those previous exercises, which did not use an agent, had used different existing scenarios, except in the case of one of these five students, the first-year master's student, who had experienced the role-play exercise using the same scenario as we used in this experiment, although without an agent on the earlier occasion. The other five students had no prior experience of role-play training for project management education.

A. Experimental results

Table 2 shows the number of messages exchanged by each learner, the average message length in characters, the number of times previous cue cards were referred to, and the role-play execution time.

1) Role-play exercise execution time

Four groups, group 1, 2, 3, and 4 were able to finish the role-play exercise within the estimated time, which is about 60 minutes. However students in these four groups may not have exchanged enough information to make the best decision. In contrast, group 5 spent much more time on the role-play than the estimated period and exchanged five times as many messages as other groups did.

2) Number of messages exchanged

It is known that students in group 5 exchanged a large enough number of messages to practice the skill of team building because the chat log shows a change of the students' way of thinking about team member selection. Also, this group did not violate the law in handling of confidential information.

Figure 3 shows the relation between the average length of messages, measured as number of characters, which the two learners sent or responded to. One player sends more messages another player also sends more messages. The correlation coefficient of two lengths of message exchanged by the two learners is 0.92. If one player were an agent and exchanges many useful messages, other players who are students might be well trained.

3) Behavioral track records of each learner

Figure 4 presents the behavioral track record of students in group 5 from phase 3 to phase 9 in the role-play scenario. The students regularly referred to earlier cue cards after receiving many messages from agents in order to analyze the information delivered by the cue cards and gathered by chat. The agent's messages may motivate students to exchange information because Figure 3 indicates that one of players, even though the player was an agent, sent longer messages and this resulted in the other participant also sending longer messages.

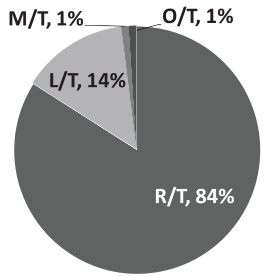

Figure 5 Message ratio of R, L, M, and O

4) Categories of messages exchanged

Chat messages were categorized into four types as follows: message as a role-player, R (Role-play); message about lesson or practice, L (Lesson); message about manipulation of role-play, M (Manipulation); other messages that do not fall in any of the above categories, O (Other) [5]. The total number of messages for all Groups, T, was 116.

The value of the message ratio R/T indicates how seriously a learner is immersed in the role of the stakeholder described in the scenario. The value of R/T is larger when a learner is more seriously immersed in the role described in the scenario. Similarly the value of (R/T plus L/T) is larger when new learners in the experiment were becoming familiar with the process; the value of R/T plus L/T was 98%, as shown in Figure 5.

B. Questionnaire survey

After the role-play students answered questions on whether they had been able to share the required information, to be conscious of their roles, and to visualize the work of project management through the role-play exercise.

1) Information-sharing

Figure 6 shows the results of the survey question about information-sharing during the role-play exercise, without an agent and with an agent, and the effectiveness of using an agent. 32 third grade students practicing the role-play without an agent answered this questionnaire and, of these, 66% felt positive about the feasibility of information-sharing while for the 10 participating students studying the role-play with an agent, 70% felt positive. Similarly, 31% of students who took part in role-play without an agent had negative feelings, but of the students participating with an agent only 20% felt negative.

In order to investigate the effectiveness of introducing agents into role-play training, we asked five learners who had experienced a role-play exercise on at least one previous occasion whether they were able to get the information required for the role-play exercise through chat, both with agent and without the agent. Two students felt that were able to obtain the information required for the role-play more effectively with the agent than without it. Another two students also recognized the advantages of adding an agent into the role-play training. Therefore we have deduced that the use of an agent may help learners share the information required to take part in a role-play exercise.

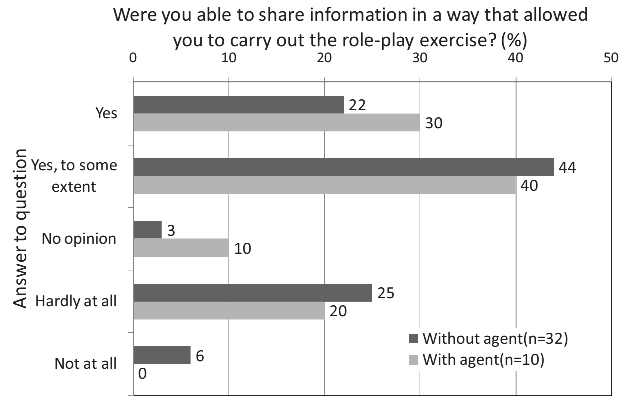

Figure 6 Information-sharing with agent / without agent

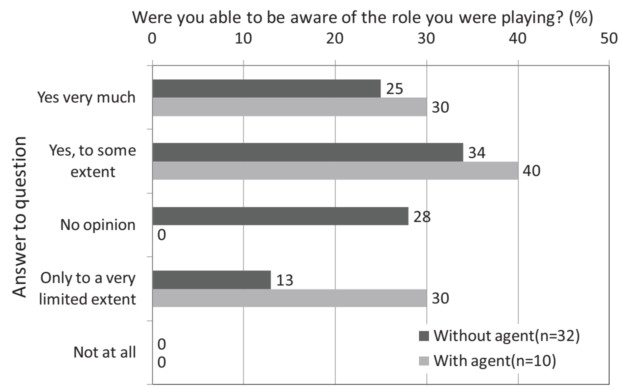

Figure 7 Awareness of role in role-play

2) Awareness of role in the role-play

Figure 7 shows the results of the survey question about the awareness of their role as a stakeholder, for students participating without an agent and those participating with an agent, to determine the effectiveness of using an agent.

Without an agent, 59% of students felt they had got into the character of a stakeholder, while for students participating with an agent, the Figure was 70%. This increase of 11% may arise from the powerful incentive of students doing the role-play exercise with an agent. Only two out of the five students said that the agent might encourage students to immerse themselves more fully in the role of a stakeholder. Some students answered an additional free response question about the effectiveness of using an agent. These answers were: they were able to get the feel of working in a real project because the information about the stakeholders whose roles were not assigned to learners was presented to students through the chat; and they were able to be immersed in a character and could understand what they should say in the chat session because a statement from the agent had provided a good example.

3) Ability to imagine a real project

Three students who had experienced previous role-play training were able to imagine a real project through participating in a role-play exercise with an agent taking the part of other stakeholders.

IV. DISCUSSION AND FUTURE WORK

A. Analysis of chat log data

From the data in Table 2, group 5 spent three times the length of time and exchanged three times the amount of information, compared with other groups, even though student 10 had no experience of role-play training.

The major reason for this significant difference is that the student 9 had experienced the earlier version of the role-play scenario, was seriously immersed in the role of the stakeholder, and so probably acted as a mentor to the others.

The two students in group 5 were both graduate students and so may have taken the role-play more seriously. If an agent were able to play the role of a mentor in the role-play, role-play training including such an agent might be a powerful tool for project management education.

According to the results of the questionnaire survey, the use of an agent may help information-sharing among learners, may help learners understand their roles as stakeholders, and may help learners imagine what it is like to participate in a real project.

B. Future work

We plan to pursue our research based on the principle of using an NPC (Non-Player Character) as follows: in the next stage, an agent will let learners know the information needed for decision-making and encourage them to acquire information, and ensure information sharing; in the following stage, an agent will evaluate alternatives for decision-making by learners; in the next stage, an agent will act as a mentor in proposing alternatives to learners making a decision; and finally an agent expressing human emotion will be provided in order to simulate practical team work in a system development project.

Scripting all of alternative scenarios which may be derived by a learner while a role-play exercise is running is typically labor-intensive. A method for automatically generating all alternative scenarios should be established. In order to generate the behavior scripts for not only a learner but also an agent, case based reasoning (CBR) may be applicable to create scenarios [11].

V. CONCLUSIONS

The aim of this research is to use an agent system to provide the function of a mentor in order to realize project management education for students who have no practical experience of project management; this will enable them to learn human-related skills such as communication, leadership, and team building.

This paper reports work which leads to the conclusion that agent can be useful in helping learners to share information, to understand their roles as stakeholders, and to visualize the job of project management. It would be very helpful to develop an agent system which can solve the problem of how to improve human-related skills. We will define an observable evaluation metric which can be used to evaluate the effectiveness of learning human-related skills by using the concept of NPC. We will also seek to implement human characteristics in an agent.

ACKNOWLEDGMENT

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Game-based learning in technology management education

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Abstract— **Management games allow students to obtain valuable first-hand experience that is of particular value in a field such as technology management, which usually involves substantial risk as well as significant time lags between a managerial decision and its effects. In drawing from more than fifteen years of experience with management games in higher education, we have developed a management simulation for teaching technology management, a field that is increasingly regarded an important area of study for engineering students. This paper outlines a blended-learning design for a course on technology management, describes the various didactical elements as well as their effects in class, and addresses the technical implementation of the management game as a service-oriented multi-tier application in Java.**

Keywords-experiential learning; management game; simulation; technology management

I. Introduction

Technological innovations are essential for the success and survival of firms in today's dynamic market place. It is therefore not surprising that managers devote large amounts of resources to research and the development of new technologies. At the same time, uncertainty regarding the success of technological endeavors is typically high. Given its strategic importance, the resources at stake, and the substantial risks involved, a systematic approach to the management of technology is considered indispensable by both the scientific community and practitioners.

Consequently, technology management has become a highly relevant area of study – not only in most business schools [1], but also in engineering management education, that deals extensively with technology management issues as means to bridge the gap between the fields of engineering and business (for examples in the US cf. [2]). This is also true for vertically-focused engineering curricula, which are however giving way to integrated programs encompassing multiple disciplines [3]. Accordingly, an increasing number of engineering programs integrate technology management in their curricula, thereby strengthening the trend towards broader scholastic experiences by offering engineering students an interdisciplinary perspective.

In practice, corresponding technology management courses more often than not are taught in a "traditional" lecture format that may be complemented by case analyses [4]. Management gaming (also commonly termed "management simulations", "management (flight) simulators" or "business gaming simulations"; for an overview on the history and a discussion of the differences in terminology cf. [5]) have been applied successfully in many areas of management education for more than 40 years [6-8]. However, they do not appear to be used prevalently in technology management education.

As means for experiential learning [9], management games allow participants to assume the role of decision-makers that compete against each other in a "safe" artificial environment. By shortening real-world decision cycles from years or decades to hours or minutes in the simulation, the learning process can be accelerated dramatically, which should help participants to gain a better understanding of the real-life situation the simulation game refers to. The main objective of using management games as tools to enhance learning is to give participants the opportunity to apply theoretical knowledge in close-to-reality situations in order to develop decision-making competence, rather than solely acquiring theoretical knowledge. In a well-designed and implemented simulation, this may lead to the synthesis of theory and practice [5]. Management simulations can thus be seen as an appropriate response to the criticisms against the "knowledge acquisition approach" (cf. [10]) in management education. They are especially useful in fields like technology management, where delays, the large amounts of resources at stake, and the high risk involved prohibit real-life experimentation.

The remainder of this paper is organized as follows: Section 2 delineates the conceptualization of the game and discusses thematic aspects covered in the simulation. Section 3 outlines how the management simulation is embedded in an overall didactic design. Section 4 provides details about the implementation as a service-oriented multi-tier application in Java. The paper concludes in Section 5 with a summary and an outlook on further research.

II. Conceptualization

In developing a management simulation for Master-level students, we could draw upon more than fifteen years of experience with management games in higher education, which allowed us to "cherry-pick" the most effective didactical means in order to tweak the learning outcomes. To account for the integral nature of decisions in the field of technology management, the simulation also comprises elements from other areas such as marketing, production, and finance, and may thus be considered a total management simulation. The main emphasis, however, is on the strategic planning of research and development (R&D) investment, the adoption of and migration to new technologies, and the management of patents and licensing. The simulation is generic in that it does not represent any specific industry, but can be tailored through parameterization using an instructor tool. The tool also allows for the creation of scenarios with varying degrees of complexity through optional features, such as stock-keeping, cooperative research or patents and licensing. Furthermore, the instructor may define all functions by setting control points and selecting linear, polynomial or cubic spline interpolation.

In each game, a single participant or a group of participants takes control of a virtual firm. At the beginning, all firms are homogeneous in that they possess the same amount of initial capital, the same amount of knowledge and an equal number as well as equal kinds of products and production facilities. Each game follows an iterative process in which participants are supplied with various reports on the performance of their firm that they may use to evaluate their strategy and possibly adapt it before submitting their decisions for the next period. As soon as all decisions for a period have been received, the results are processed automatically and financial statements and additional reports are generated before the game proceeds to the next round. This procedure is repeated until some terminating condition, such as a pre-determined time or a number of periods, is met or until the instructor ends the game manually.

Firms compete in a simulated market by developing and launching products. Before doing so, they need to conduct (basic) research to accumulate knowledge, which eventually leads to the "discovery" of advanced technologies. When such a new technology becomes available to a firm, it may be adopted and serve as a basis for subsequent product development. The resulting products are characterized by a number of attributes which are defined by the instructor, who may choose generic measures such as functionality, performance, usability, durability etc., or scenario-specific measures relevant in the simulated industry (e.g. engine performance, safety or handling in the automotive industry). Strategic decisions regarding resource allocation are a key element of the simulation. Participants need to weigh investments in research (which may lead to breakthroughs and performance leaps in the long run) against investments in the development of more sophisticated products based on current technology and/or against investments in process development (which reduces production costs). Once a technology becomes available, participants need to determine a plan for investing in the new technology and for phasing out existing technologies. Thus, participants may test various strategies, such as early adopter or fast follower strategies, and experience their respective advantages and drawbacks.

As soon as a satisfying performance increase has been achieved in a technology, firms may decide to launch new products at the market where they compete for market share with existing products that consumers are already familiar with. In our management game, we used an agent-based approach for simulating the diffusion of information about new technologies and products through the social network of consumers. To generate realistic diffusion patterns and simulate buying behavior observed in the real world, the instructor may divide the market into several heterogeneous segments with distinct characteristics regarding propensity to innovate, preferences, price sensitivity, brand loyalty, sensitivity to advertising, and communication behavior, which determines the diffusion of information about new technologies and products in the segment. Revenue generated from product sales is used to cover costs of production, stock-keeping, business intelligence and licensing, among others. Profits may be reinvested in research, development of the various performance dimensions of technologies, process development, construction of new production facilities, or advertising.

Once a game has ended, participants receive a final report that summarizes results and provides more detailed information that is not available during the game. Overall participant performance is measured by equity held at the end of the game as well as by the amount of technological progress achieved.

III. Didactic Design

In a management game, participants interact with/within a modeled system that represents a part of reality. These interactions follow a general course (see Fig. 1) where participants choose actions through decisions that are then entered – either directly (as in the online version) or via an instructor (as in the offline version) – into the simulation program. Based on these decisions and global conditions (such as market, inflation etc.) the system reacts according to the rules of the implemented model. Finally, feedback (e.g. on market development, sales etc.) is provided to the participants through various reports that, in turn, form the basis for further user action, thus restarting the loop.

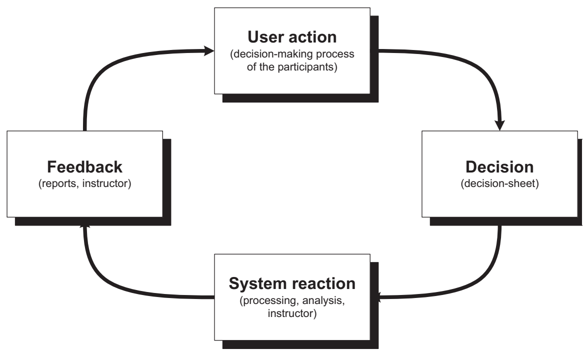

Fig. 1. General course of a management game.

Even though this general course, and therefore the management simulation itself, forms the center of the didactical frame, it has to be embedded into a broader (blended) learning concept to meet the learning objectives. To this end, the simulation game is not only played with various settings, levels of complexity and difficulty in both online and offline environments, but is also supplemented with accompanying measures and tasks. Furthermore, the management game can be embedded into a broader course design, as (engineering) students need to possess at least basic knowledge about technology management before engaging in the game. At the University of Vienna's Faculty of Computer Science, for example, the management simulation is integrated into a larger course that commences by imparting basic theory, provides students contact with business practitioners by means of excursions and invited talks, and also requires the preparation and discussion of case studies on technology management in class (see Fig. 2). Thus, participants are well prepared when they start to play the gaming simulation.

The didactic concept of the management game is illustrated in Fig. 3. Before the first game is started, participants are briefed on the overall setting as well as on technicalities concerning the decisions they need to make. However, no details about the inner workings of the game are revealed, since the participants should learn by doing. Next, a first (offline) introductory game is played in class, which bears

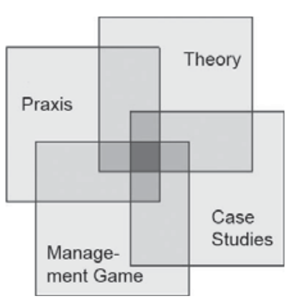

Fig. 2. Integration of the management game in a course design.

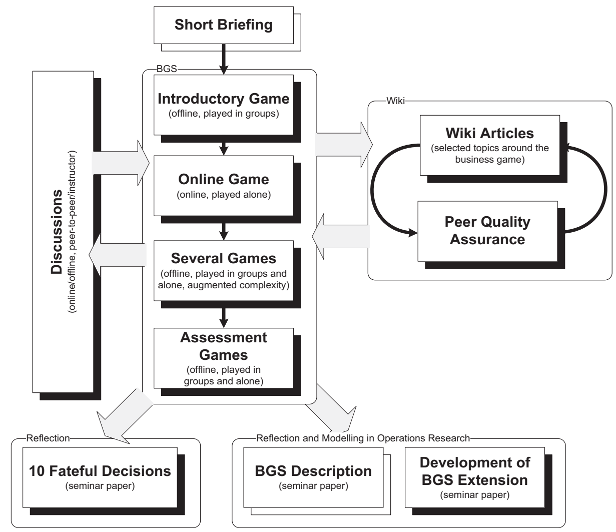

Fig. 3. Overview of the didactic concept of the management game.

several advantages. First, the instructor may directly react to questions without the typical time lag that occurs in an online setting. Second, the participants' decision-making process may be observed, which helps to spot problems or mistakes. Also the atmosphere within the group can be monitored more easily in a classroom setting, which helps to prevent frustration as a consequence of unexpected results. Even though direct assistance might be one possibility, following the learning-by-doing approach the instructor should concentrate on the stimulation and moderation of the discussion between participants. Moreover, students can, should and do help each other when performing tasks like calculating a "good" price, analyzing data, drawing graphs etc. To encourage peer-to-peer interaction during the first game, each firm is managed by two students at the beginning. As the participants should focus on the technology management aspects instead of the intricacies of a web-interface, the decisions are submitted on simple paper forms at this stage. The instructor enters the data manually and delivers the results on paper, which provides the opportunity to directly give (additional) feedback. However, these advantages of the offline version come at the cost of an increased workload so that generally more than one instructor is needed at this stage to process the data. Finally it should be noted that the complexity of the simulation is reduced during the introductory game by disabling optional aspects such as patents or licensing.

Once the initial game has ended, the web user interface is explained thoroughly to the participants in order to avoid difficulties during the subsequent online phase. During this phase, the game is played online over a time period of six weeks with two decision rounds per week. As opposed to games played in a classroom setting, participants can analyze their strategies and prepare their decisions without any time pressure. Also, in contrast to the first game, each student is fully responsible for managing their own firm in order to prevent free-rider problems. Nevertheless, both peer-to-peer and student-to-instructor communication is crucial and thus encouraged also in the online phase by providing proper channels like web forums. Experience shows that these communication channels are primarily used for questions to the instructor, while peer-to-peer interaction hardly takes place online. However, anecdotal evidence suggests that informal information exchange between students does occur offline (e.g. in the cafeteria), but is limited to selected colleagues, which indicates that students apparently regard information asymmetry as a key strategic advantage that they try to sustain. Note that the discussion forum is currently not part of the management game itself. Instead, the communication features of a learning management system (LMS) are used, which constitutes a "media disruption".

During the online phase, participants are required to prepare papers on selected topics related to the management game in order to complement the learning-by-doing approach with more theoretical reflections. The articles are co-authored in groups using a Wiki, which is integrated in the LMS. According to our experience, collaborative online writing appears to be a new concept for most of our students, which is why a basic introduction on the use of Wikis is (still) crucial. This task allows participants not only to gain experience with a new form of collaboration, but also enables them to share with other students what they have learned about the theoretical concepts embodied in the management game. This knowledge is essential for meeting the learning objectives of the course, which obviously go beyond winning the management game. A problem we frequently encountered was that students hardly ever read the articles of other participants, which may partly be attributed to the low quality of some contributions. To alleviate this problem, we decided to introduce peer quality assurance mechanisms. Upon completion of the initial Wiki writing process, every group is appointed to be responsible for an article of another group, in order to (i) improve it and (ii) write a summary. Log files show that students do not only read the article they are asked to improve, but also most other articles, possibly for comparison and inspiration purposes. A potential problem with this approach is that we frequently observe strong reservations against editing the work of others. Also, the imbalance of the workload poses a problem since some articles require more improvement than others.

The online-phase is followed by a final phase of attendance for two and a half days in class where additional games are played at a higher level of complexity. Whenever new aspects such as stock-keeping or licensing are introduced in a game, participants form teams of two students each managing a single firm to allow for reflection on and discussion of the new challenges. We also observed that information exchange typically does not only occur within each group during these games, but also between groups and thus among competitors. However, this willingness to cooperate tends to decrease as the ambition to win the game rises at a later stage. This holds true particularly for the final assessment games, where students can earn points that contribute (at a low percentage) to their grades. By including the gaming results into the grading scheme, we provide incentives that appear to be efficient in that they considerably enhance the involvement of students.

Reflection on actions and decisions plays a vital role in all management games. In addition to regular feedback during the game and in the discussions, participants therefore are required to individually reflect on their decisions and the whole management simulation at the end of the course by writing three seminar papers. In the first one, students report on their "ten most fatal" decisions and their consequences. Besides describing the circumstances and the mistake they made (e.g. failure to properly take inflation into account when determining prices), participants should also discuss possible strategies to avoid the respective problem. In order to foster understanding of the underlying model, students are required to produce a second seminar paper that describes basic elements of the management simulation and their interrelationships, both conceptually and formally. This serves as a starting point for team discussions about suggestions for extensions and improvements of the game, which result in a third seminar paper. Upon elaboration of this final paper, students concern themselves with methods of quantitative modeling. For most students, this phase serves as a "gentle" introduction to model building and simulation, which may be considered an additional benefit.

IV. Technical Implementation

A computer-based simulation that can be used in the didactic design outlined in the previous section has to meet a number of key requirements. To begin with, the application has to support multiple usage modes in order to allow for various educational settings. For instance, during the first phase of the didactic process outlined in the previous section, which takes place in a classroom, the game is run locally on a single computer; the second phase is Internet-mediated, which implies that an intuitive user interface is required to allow participants to submit decisions and analyze results easily; the third phase is again conducted in a classroom setting where each participant uses a dedicated computer connected to a local area network. Moreover, participants cannot be expected to install additional software on their computers. They should rather be able to use any standard-compliant web browser on any platform to submit their decisions and access reports. Further to this, the application core itself should be platform-independent, as it is used both locally on Windows-based computers and on dedicated application servers running

Linux. Moreover, it was decided that the implementation should rely on freely available software. Major design objectives were stability, resistance to manipulation, and extensibility of the system.

Next, a number of major functional requirements were identified. First, the application must provide an intuitive web-based user interface. Participants should be able to focus their attention entirely on the simulation rather than being distracted by usability issues. Second, the application should provide the instructor with extensive capabilities for model building in order to give her the freedom to create arbitrary scenarios. To facilitate the complex parameterization process, the system needs to provide appropriate mechanisms such as the ability to define smooth functions interactively in a graphical way. Third, it should be possible to tailor the simulation to the needs of both novice and experienced participants by limiting or extending the decision space during parameterization. Finally, the system must give ample and easily understandable feedback to provide a solid base for decisions and facilitate an effective learning process. Considering all functional and non-functional requirements, we chose Java Enterprise Edition [11] as an implementation platform and developed a distributed application consisting of four major components, as illustrated in Fig. 4.

The central component that manages user accounts and game instances and executes the simulation model is hosted on an application server. It provides a web-based interface for participants as well as remote services for an instructor client, which is used for the creation and parameterization of game instances, user account administration, assignment of participants to games, and entering decisions for participants in the second phase of the didactic process. The application server connects to a database server providing persistence.

Applying the concept of multi-tier architectures, graphical user interface, business logic, and persistence layers are strictly decoupled and the resulting services are connected through interfaces. This clear separation has significant benefits in terms of maintainability and extensibility, as it results in a modular system of independent components that can be exchanged or modified easily without affecting other parts of the system. Another key advantage of this approach is that it is relatively easy to connect multiple independent presentation layer components, such as a web interface for participants and an application client used by instructors. Finally, and possibly most importantly, a multi-tier approach is a good way to support the parameterization of management simulations for multiple educational settings, where for example the number of players, the scenario to use and the underlying simulation model may differ each time (cf. [12]).

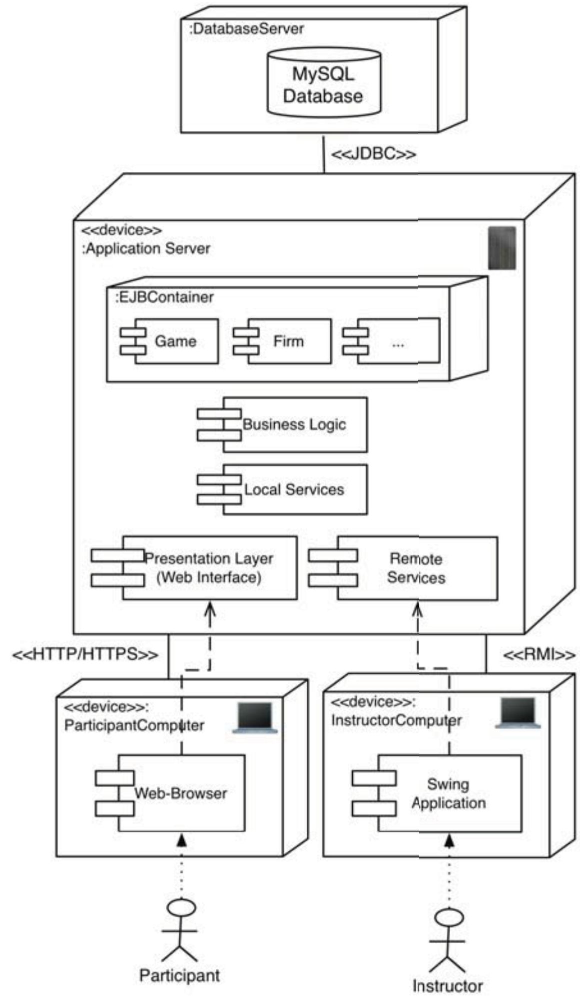

Fig. 4. Deployment diagram.

The individual components depicted in Fig. 4 can be distributed across several computers or run on a single machine. The core of the system is deployed on a JBoss J2EE application server, which is purely Java-based and can thus be run on a large number of operating systems. Container-managed persistence, a technique where the object-relational mapping is handled by the J2EE container the application runs in, is used to preserve the state of objects to a MySQL database. The web-interface relies on Java Server Faces, JSP, and Java Portlets. The instructor client is implemented in Java Swing and connects to the application server via remote method invocation (RMI). It provides a rich user interface, does not require installation, and is platform-independent. For an illustrative example of its use, see Fig. 5.

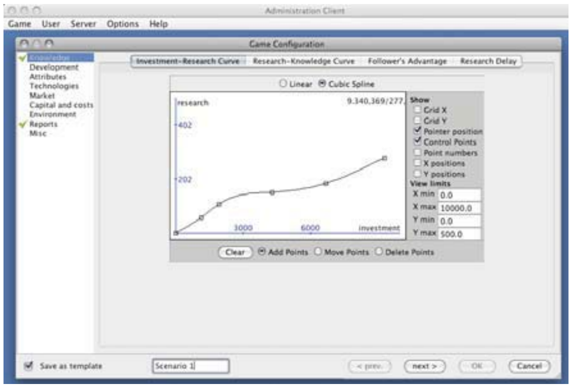

Fig. 5. Scenario creation using the instructor tool.

V. Conclusion

The management game introduced in this paper complements more "traditional" instructional methods commonly used in technology management education in a blended-learning course design and provides an excellent opportunity for students to gain relevant first-hand experience through learning-by-doing. The service-oriented architecture of the application facilitates its use in various educational settings and its adaptation to the specific needs of participants. Learning success, however, is not solely determined by the quality of the underlying simulation model or its technical realization. These factors must rather be considered necessary conditions. When it comes to achieving learning outcomes, the integration in a broader didactic design plays a key role for success. For this reason we suggest combining the game-based learning approach of the management simulation with various additional elements into a didactic design that encompasses (i) continuous peer-to-peer knowledge exchange, both on- and offline, (ii) teamwork and team play, (iii) written ex-post reflection on decisions and discovered relationships, (iv) suggestion of extensions to the simulation in a seminar paper, which encourages participants to gain a deeper understanding of the underlying model and may serve as an introduction to mathematical modeling and (v) theoretical considerations regarding various topics related to the simulation, which are prepared by participants in the form of Wiki articles. In order to assure quality of the contributions and encourage the dissemination of information among participants, these articles are subject to obligatory peer review.

Still, our management game may be complemented in several directions. First, the integration of online communication directly into the management game would eliminate the media gap caused by the use of various external communication channels and, thus, help to alleviate the lack of rich communication and information exchange during the online game. Learning blogs could be used to allow the participants to record and analyze their thoughts, strategies and decision-making processes during the game. Next, additional game options like multiple (international) markets or cross-licensing of patent portfolios with balancing royalty payments and/or the introduction of computer-controlled rivaling firms would allow for new possibilities.

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Session 01F Area 1: Intelligent Learning Systems

Continuous Proactivity in Learning Management Systems
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VenDASys – a versatile experimentation platform
Mißler, Rüdiger; Sallier, René; Schütze, Andreas
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Virtual flute: electronic device that uses virtual reality to teach how to play a flute
Galeano, Katherine Johanna; Luengas, Lely Adriana; Rincón, David Andrés
Universidad Distrital Francisco José de Caldas (Colombia)

An adaptive Multi-Agent based Architecture for Engineering Education
Agila-Palacios, Martha Vannesa; Jara-Roa, Dunia Inés; Rodríguez-Artacho, Miguel
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Continuous Proactivity in Learning Management Systems

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Abstract— **Three studies, conducted on graduate level, show findings that students with highly proactive behavior are more likely to succeed in a Learning Management System (LMS) environment. Statistical analysis techniques were used in the studies. In the second study the concept of continuous proactivity was introduced to observe if a study-group was more likely to succeed in the lesson compared to a control-group, and in the third study, proactivity was applied to the entire class. This paper reports the results of the second and third studies and introduces the concept of "continuous proactive learning strategies" to frame the future development of proactive rules in LMS.**

Keywords: Proactive Learning, Learning Management System, Learning Techniques, Learning Methods

I. INTRODUCTION

E-Learning environments, or Learning Management Systems (LMS) are a set of methods, tools and techniques to deliver learning content through the Internet or similar networks. LMS are suitable systems to support distance learning and blended learning – used in conjunction with face-to-face teaching. Over the past ten years LMS has been adopted by educational institutions, becoming almost omnipresent in many parts of the world. These systems have been designed adapting existing interactive web based technologies – relating to a program that responds to user activity – to deliver educational content.

Although there are already a large number of functions, covering a large number of users' needs for a variety of different users acting specific roles in these LMS environments, current LMS are fundamentally limited tools. They are only reactive software, content management based, and developed like classical user-action oriented software. These tools wait for an instruction, most commonly given through a graphical user interface, and then react to the user's request, limiting the value of the LMS to the user's own action and not to the needs of the learning process.

Learning is a continuous, step-by-step effort that requires conscious undertakes in order to achieve predefined learning goals. This continuous effort is orchestrated by pedagogic approaches where step-by-step strategies for instruction are defined. Different pedagogical theories exist: constructivism, resource based learning, collaborative learning, problem based learning, narrative based teaching, situated learning, etc. One of the common denominators of these pedagogical theories is the need of a continuous effort.

Proactive systems, as defined by Tennenhouse [3] adhere to two premises: working on behalf of, or pro, the user, and acting on their own initiative, without the user's explicit command. Proactive behaviors are intended to cause changes, rather than just react to changes. This is a major change from interactive computing, in which we lock a system into operating at exactly the same frequency as humans do. Proactivity is a means of continuous effort and student's continuous LMS interaction (engagement) is an approach to proactivity. Proactive Learning Management Systems (PLMS) is a new kind of LMS, designed to improve the users' online interactions by providing programmable, automatic and continuous analyses of users (inter-) actions, augmented with appropriate actions initiated by the LMS itself.

This paper reports statistical analysis observations on three studies in Proactive LMS. The first study develops a simple proactivity test-case study to answer the research question: "Are students with high proactive behavior more likely to succeed in a LMS environment?". This study was developed in a blended learning environment for a second year bachelor class during the winter semester of 2006-2007. The second study, developed during the winter semester of 2007-2008, was designed in order to observe: "Are students with continuous

LMS proactivity more likely to succeed in a lesson?". This study utilizes a study-group and a control-group to statistically evaluate if the study-group is more likely to succeed in the lesson. Proactivity was continuously triggered to provoke students' participation and interaction via LMS. The third study, conducted during the winter semester of 2008-2009, generalized the application of the ***continuous proactivity*** to an entire class in order to observe: "does continuous proactive rule have a direct positive impact in student's results?". Thus, ***continuous proactivity*** will increase the probability of student's success in a lesson. Furthermore, this paper introduces the concept of "continuous proactive learning strategies" to frame the future development of proactive rule in LMS.

II. Observations on the First Study: Simple Proactive Study

A Simple Proactive Study [2] was implemented in a blended learning environment for a second year bachelor class during the winter semester of 2006-2007. The class itself follows the normal academic program, with the LMS as a supporting tool of the learning process.

Different activities were programmed for the students to balance the learning, and more precisely, to provoke continuous step-by-step effort in order to answer the research question: "Are students with high proactive behavior more likely to succeed in a LMS environment?". Two types of reactive activities, forums and homework were available on the LMS for the students to participate and all the students' interactions were recorded. A proactivity rule was triggered two times during the semester, one early in the semester and one in the middle. The rule was based on the students' total participation in the class activities and the rule sent an email notification to those students who had not enough participation encouraging them to participate.

Statistical analysis on this study shows a 82% correlation level between the forum and homework activities and the exam results, and a 73% correlation level for online content access of the students for whom proactivity was triggered (see table I). These first results also show by 28% and 33% respectively, that proactively triggered students were more successful than those who were not.

TABLE I. Proactively Triggered Student's Correlation Analysis

Correlation	Proactive	Entire Class
Activities vs. Final Grade	0.824	0.541
→Forum Participation vs. Final Grade	0.506	0.403
→Homework vs. Final Grade	0.742	0.665
# Online Connects vs. Final Grade	0.729	0.405

III. Observations on the Second Study: Continuous Proactivity Control Study

In the first study we observed a 82% correlation between students' LMS participation, and the final results for students were proactivity was applied compared to a 54% without proactivity. A second scenario – case study – was developed to answer the research question: "Are students with continuous LMS proactivity more likely to succeed in a lesson?".

This second study focuses on continuity as means of increasing LMS user engagement, enabling the continuous step-by-step effort required to achieve learning goals. A proactivity rule was triggered six times during the semester only to the study-group, and aimed to encourage the student's participation on online Forums. The rule was event-time based, and an email was sent to all the students in the study-group on a regular basis.

The rule is defined as:

rule description: On dates D1, D2... D6 advise the study-group about the status of the online forum by email to increase their online engagement.

data acquisition:
cc = get_course(C)
sg = get_group(
tt [...]= get_dates(D1...D6)

activation guards:
date = ***tt[...]***

conditions:
es.get_all_users(study_group(cc))

actions:
sendLMSeMail(to = es.name, subject = "*Forum Info Update*", data = "*Please be informed that the forum "WBS Level Two" has been closed and graded. The forum "WBS and Mindmaps" will be closed on 16/11. These activities represent 30% of the course evaluation.*")

The LMS recorded 12,202 student interaction events for 22 students (12 in the study group and 10 in the control group). The Figure 1 shows the integration of the students' LMS daily access and the class activities over the time. In this figure it is visible that particular events drive students to access the LMS, notably the day before a class and the day of a class connections were doubled.

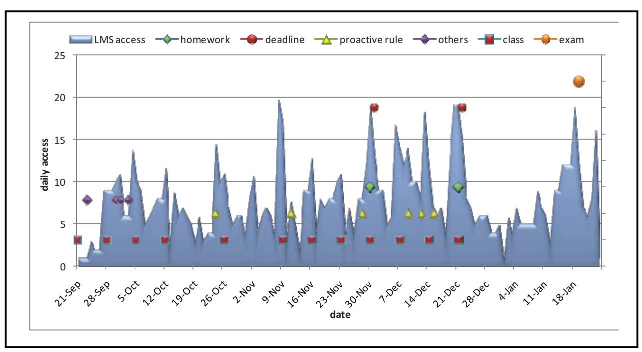

Figure 1. Interactions on the LMS

This is a logical confirmation on how the students take advantage of the LMS as source of information and knowledge.

However this is also a confirmation that students were only driven by a particular event, stimulus, in this case update their knowledge just before the class. This shows the general class trend of using the LMS intermittently and the question is: are both, study and control groups, intermittently accessing it or is there a different trend?

The study-group received six proactive rules via email notifications to create awareness of the status and availability of forum activities. Figure 2 shows the access distribution between trigger day -1 and day +3. Total traffic increased between 25% and 30% on the triggered date and up to two days after the event. This result shows that the stimulus lasts a maximum 3 days, similar to the class event where the stimulus also lasts 3 days (day -1 to day +1). The combination of these events increased continuity or student engagement in the class lessons.

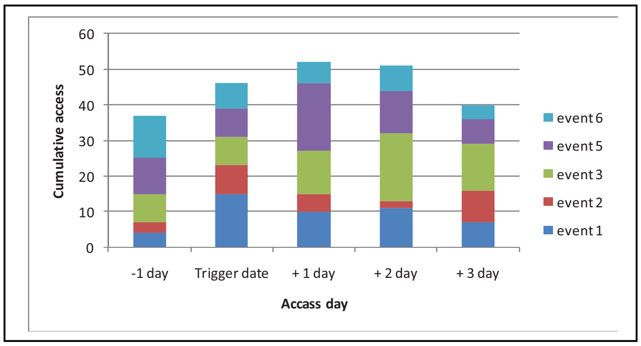

Figure 2. Study-group and control-group interactions on the LMS

To answer the research question if "students with continuous LMS proactivity are more likely to succeed in a lesson", the class assessment results were analyzed and the comparative showed 20% more success in the study-group than in the control-group. In this particular scenario the strategy was LMS engagement in order to increase the success rate. The study-group's participation in the online forums was 12% greater than that of the control-group, and assessment results were also 5% higher on the study-group compared to the control-group. Figure 3 shows the daily LMS access and events for the study-group and control-group.

Further analysis was developed to study the relation between the online forums subjects and assessment on those subjects during a final exam. Seven questions in the final exam were drawn in relation to the 13 online forums, and correlation analysis show a 7.8% direct improvement on the study-group as a result of proactivity. In summary, observations on this case show that the study-group, on which proavtivity as a mean of continuous engagement was applied, is more likely to succeed in comparison to the control-group.

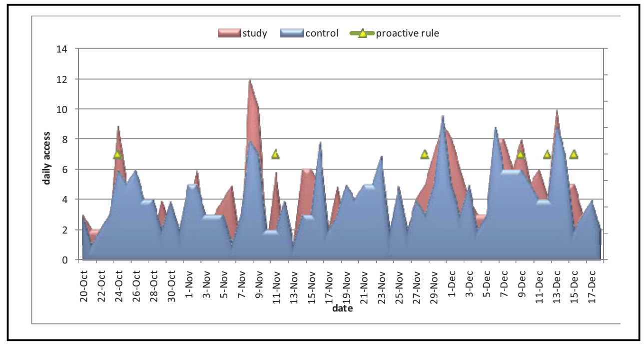

Figure 3. Study-group and control-group interactions on the LMS

IV. OBSERVATIONS ON THE THIRD STUDY: GENERALIZED CONTINUOUS PROACTIVITY STUDY

A third study, conducted during the winter semester of 2008-2009, generalized the application of the continuous proactivity to an entire class in order to observe: "does continuous proactive rule have a direct positive impact in student's results?". Consequently, continuous proactivity will increase the probability of student's success in a lesson. This third study elaborates on the observations of the second study, where a combination of events increased continuity or student engagement in the class lessons.

In this study a proactive rule, based on events, was triggered 8 times during the semester to encourage all students participation in online Forums.

The rule is defined as:

rule description: On event *New Forum* F1, F2…F8 advised students about new online forum by email to increase their online engagement.

data acquisition:
cc = get_course(C)
ee [...]= get_event(F1...F8)

activation guards:
event = ***ee[...]***

conditions:
es.get_all_users(cc)

actions:
sendLMSeMail(to = es.name, subject = "*New Forum*",
data = "*A new topic "XYZ.." has been added to your Project Management class Forum*")

The LMS recorded 5,466 student interaction events for 13 students. Figure 4 shows the access distribution between trigger day -1 and day +3 of the proactive rule. Total traffic increased 11% on trigger day and up to three days after the event, this could be seen as a decrease compared to the previous study. However, this is not the case because these events where triggered approximately +2 days after the class session to increase engagement (continuous effort) and traffic during class window increased 13%. This shows an overall 12% increase during the combined events, proactive plus scheduled class session, with a stimulation effect lasting more than 4 days in some cases.

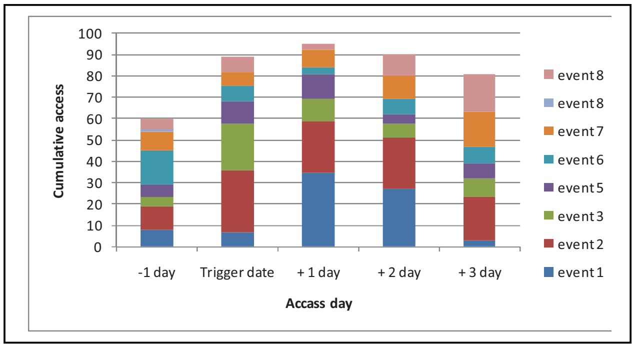

Figure 4. Third study interactions on the LMS

The Figure 5 shows the integration of the students' LMS daily access and the class activities over the time, showing a similar trend to previous studies where LMS access around an event increased.

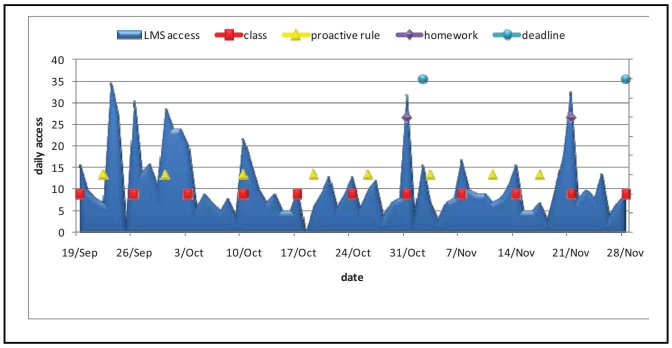

Figure 5. Third study interactions on the LMS

In this study, statistical analysis was carried out on the relation between grade results and the student's activity in the online Forums as a result of the proactive rule. Analysis on the Forums participation was done based on type of action performed by them. Three types of actions where registered; (a) create a new entry in a forum, (b) read an entry and (c) respond to an entry.

TABLE II. Correlation analysis between forum online actions and activies, exam and final grade

	Forum Online Actions		
	new	responses	read
Activities	0.50	0.32	0.60
Exam	0.54	0.41	0.56
Grade	0.61	0.42	0.68

Table II summarizes the correlation analysis. Analysis shows a 68% correlation level between students's reading the online forums and final grade, compared to 61% by new entries and 42% for responding to other students entries. This results shows that there is a direct relation between continuous proactive triggering and students success, 68% for this population. Notably reading forum entries has a 28% higher relation in the final results compared to responding to a forum entry.

V. Future work: Continuous Proactive Learning Strategies

The results of these studies cannot be considered as general conclusions, even if all three studies show a positive relation between proactivity actions and student's success. In order to further research the benefits of these observations, the creation and validation of proactive rules will be required which implies the definition of learning strategies oriented to stimulate the "continuous step-by-step effort" required in the learning process. These strategies are called Continuous Proactive Learning Strategies (CPLS).

The creation of proactive learning strategies requires the understanding of the factors involved in the learning process. Bransford [1] indentified 4 main factors in the learning process: attention, motivation, emotions, and experiences of the learner (progression).

- Focus of attention determines if a student mentally follows a class and, therefore, the degree of behavioral change. LMS requires a strategy for getting and keeping the student's attention on the learning content and activities presented.

Attention *is the cognitive process of selectively concentrating on one aspect of the environment while ignoring other things*

- Motivational states of students are of importance for stimuli given by the teacher or LMS to trigger the learning process. The willingness to learn results from different motives beginning with the intention to achieve something, competing against colleagues, helping other people, or emotional factors like anxiety. Motivational aspects for LMS may also depend on learning content, pointing out the relevance of an instruction or including interactive media elements such as online discussions, debates, games and simulations.

Motivation *is the internal condition that activates behavior and gives it direction; and energizes and directs goal-oriented behavior.*

- The emotion is an unconscious system to alert us on potential opportunities or risk, it triggers positive or negative motivation and attention responses. Triggering the student's emotional channel could improve the learning process and could be achieved in a LMS through storytelling, empathy, provocations, animations, and group works, enabling participation in the learning context.

*An **emotion** is a mental and physiological state associated with a wide variety of feelings, thoughts, and behavior*

- Knowledge transfer can be improved if students relate prior knowledge, either in the same domain or in a similar context. LMS learning strategies need to detect lack of knowledge at an early stage and more importantly, lack of progression during a learning cycle.

***Progression,** a learning principle which states that the benefits accrued from learning will continue only if knowledge is gradually learned.*

The proactive strategies need to create an adequate environment to activate these 4 main learning factors and enhance the continuous step-by-step effort. Strategies can be divided into two types: pattern recognition and event based.

- Event based strategies monitor the currents of events such as time and status of an action, and focus on increasing student LMS engagement. These strategies main objective is to enable attention, motivation and emotion.
- Pattern recognition strategies are continuous assessment of the student's LMS performance to determine the student's learning trend. These strategies main objective is to enable progression

The proactive strategies are to be activated via rules to evaluate the time/status events and patterns. The activation of a rule will generate a synchronous or asynchronous interaction back to the students. The asynchronous interaction could be achieved by the use of standard email or SMS based notification, however this mode of communication does not guarantee the reception and processing of the notification. Asynchronous interaction is still a valid mode of proactivity and the three studies have shown positive results when used in combination with a reward system. Synchronous communication modes achieve greater levels of engagement. This category groups technologies such as instant messaging, chat rooms, microblogging, traditional class and tutoring sessions, which could be used as a result of a proactive rule.

Future work will define and experiment event and pattern strategies to validate their impact in the learning outcome. The proactive strategies need to be combined with the mode of communication to cover the 4 learning factors. Different modes of communication have different levels of impact in the learning factors, e.g. emotion could be achieved in a tutor one-to-one session, but it would be very difficult to achieve it via email notification, nor to measure it automatically. Another example is the use of instant messages or microblogging to engage students in learning based reward activity, such as solving a particular problem and receiving points for it. The table III summarizes the expected impact, to be studied, for different mode of communication and the learning factors, "+++" meaning higher positive impact to "+" for lower level of positive impact.

TABLE III. Impact of communication modes

	Attention	Motivation	Emotion	Progression
email		++		+++
SMS		+	+	++
instant messaging	+	+++	++	++
chat	+		++	+
micro-blogging	+	+++		+
class session	+++	++	++	
tutoring	+++	+++	+++	

VI. Conclusions

This paper reports the statistical findings of two new studies on proactive LMS, oriented to stimulate the continuous step-by-step effort required in learning. On one study (second study) the question: "Are students with continuous LMS proactivity more likely to succeed in a lesson?" was answered with the observation that the study-group performs 20% better than the control-group. The third study answered the question: "does continuous proactive rule have a direct positive impact in student's results?", Showing that active online participation in class forums is linked (68%) with the student's grade results. The result of these studies cannot be considered as general conclusions, even if all three studies show a positive relation between proactivity actions and student's success, because the subject matter and populations were limited, a total of 75 students in three different calendar semesters have been observed.

The paper also describes the future work required to exploit the observation of this studies with the creation and validation of Continuous Proactive Learning Strategies.

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VenDASys – a versatile experimentation platform for educational purposes

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Abstract— **In this paper we present an approach to increase the interest of pupils and high school students in modern science and technology. To achieve this, we developed a versatile experimentation platform for the use in schools and school projects, called VenDASys (*Versatile Control and Data Acquisition System*). VenDASys allows the interfacing of individual (micro-)sensors or complete experimental set ups while minimizing the required electronics, which are often frustrating for students and teachers alike due to limited experience in this field. Thus, students (and teachers) can directly concentrate on and successfully deal with different sensors and experiments based on these sensors. We present the concept with an example project on blood pressure monitoring. Getting involved in comprehensible MEMS (*Micro Electro Mechanical Systems*)–applications and solvable problems at a relatively early stage of their education will definitely increase the chances that high school students decide to choose a technical education later on.**

Keywords- open experimentation platform; micro-sensors

I. Introduction and Motivation

In the last years the gap between the need and the availability of qualified personnel has been increasing in many technical and scientific fields. One direct consequence is the current drastic shortage of engineers. This problematic situation has been addressed in many activities around the world in didactics and education in different ways, e.g. [1, 2]. The MEMS industry in Germany already regards this issue as a major challenge for future economic success. For this reason, in 2002, the German Federal Ministry for Research and Education (BMBF, *Bundesministerium für Bildung und Forschung*) initiated the foundation of six networks focusing on MEMS education and training [3]. One of the major goals of these networks, and especially for the network "pro-mst" [4], was to counteract this trend by increasing the interest of high school students in natural sciences and engineering.

Our learning lab SinnTec (*Sinn für Technik – Technische Sinnesorgane*) was founded as result of our experiences within the network "pro-mst". SinnTec addresses both high school students and teachers to gain hands-on experience. One of the major topics of this lab is to show where MEMS technology is used today, e.g. in a car. Secondly, students should actively work with microsensors as technical senses to gain a deeper understanding. From these activities [5] we learned that difficulties in working with sensors do not primarily arise from the basic understanding of sensor function principles or MEMS production processes but from the electronics required for sensor read out and its useful application.

Based on this experience, we developed a universal and modular experimentation platform for use in schools and school projects with an open source concept allowing exchange of experiments between schools, teachers and students [6]. The VenDASys platform offers a very comfortable and straightforward opportunity to deal with sensors by simply "bypassing" most of the electronics from a didactical point of view. Thus students and teachers in a simple way gain access to the field of MEMS in particular and science and technology in general by realizing their own ideas for experiments.

II. Technical Concept

The VenDASys consists of three main parts (Fig. 1): (a) a hardware platform providing basic functionalities like power supplies, measurement inputs and digital IOs plus dedicated sensor interfaces, (b) a multi-purpose software tool with graphical user interface (GUI) implemented in LabVIEW, NI, and (c) dedicated sensor modules for different applications. The hardware platform is connected to a PC via an USB interface; individual sensors are connected to the platform via standard lab-cables, especially during the development phase. When application specific sensor modules have been realized, they can quickly be connected via dedicated Sub-D25-interfaces with power supply, analog and digital in- and output as well as data exchange. The LabVIEW-GUI gives the user full access to a variety of hardware functions (mainly analog and digital in- and outputs) without having to address the hardware set up in detail. A more detailed description is given below.

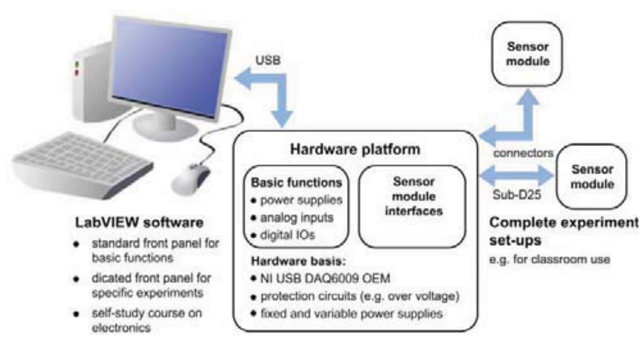

Figure 1. System overview VenDASys

This work is supported in part by the Saarland Ministry of Economics and Science. We would like to thank for the financial support.

A. Hardware platform

The electronic hardware of the system consists of several modules, with the core of the VenDASys being an USB DAQ 6009 OEM module, a commercial data acquisition system manufactured by NI. To prevent damaging the module during the course of development work by inexperienced high school students, we added additional protection circuits, i.e. against overvoltage, short circuiting or polarity reversal. The main task of the DAQ module is the acquisition of analog and digital inputs from sensors, switches etc. Furthermore, the DAQ controls the digital outputs of the system which can be used for control purposes as well as variable voltage and current sources which can again be used for control purposes or to supply external circuits. Further modules of the VenDASys are constant voltage sources (for supplying external electrical circuits), relay circuits (for switching periphery requiring higher power) and finally a separately oscilloscope with an integrated signal generator. Table I gives an overview of the integrated hardware functionalities.

TABLE I. OVERVIEW OF VENDASYS HARDWARE FEATURES

Features	Detailed properties
5 power supplies	• constant voltage source +5V/+1A • constant voltage source +11V/+1A • constant voltage source -11V/-1A • 2 variable voltage sources ±11V or 2 variable current sources [0-100] µA, [0.2-1] A
8 analog inputs	• ±10 V range, 14 bit resolution • 8 channels for absolute voltage measurement or 4 channels differential voltage measurement • overvoltage protection
oscilloscope	• 250 kHz, 2 MSamples/s • 2 channels • integrated signal generator
12 digital in- outputs	• TTL level • high impedance input • over voltage protection
2 relay circuits	• maximum voltage 250VAC/60VDC • maximum current 15A
2 sensor module interfaces	• 25-pin sub-D interface mapping all front-panel functions

By connecting sensors and other elements to the hardware platform, the need for separate power supplies, instruments etc. is obviated. The VenDASys platform therefore performs all the functions of a small electronics laboratory. For the acceptance by students and teachers alike, the proper, robust and transparent function is of utmost importance. We have therefore balanced the complexity of system, i.e. the number of in- and outputs, with the simplicity of use. For this, the module interfaces are especially important as they allow setting up complete experiments with just one connection. Fig. 2 shows the front-panel of the hardware platform with the different features.

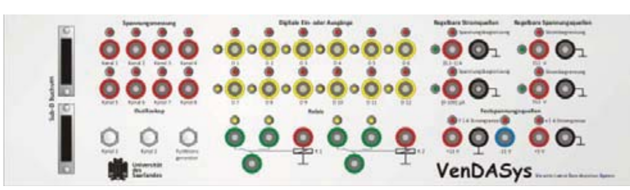

Figure 2. Front panel of the hardware platform

The DAQ module and the separately oscilloscope comes with LabVIEW software tools allowing an easy handling of the front-panel functionalities, when connected to a PC via USB.

B. Software tool

The PC software is implemented in LabVIEW because of its wide spread use in measurement applications. LabVIEW is a graphical programming language developed and optimized for the use in measurement and automation, which is divided in two basic parts: the block diagram and the front panel. The block diagram represents the programmer's working area while the front panel (example shown in Fig. 3) acts as the GUI of the completed program. The benefit for students and teachers is, that minimal experience with the programming language is required to develop programs with attractive optics for control and data display, as standard elements from the LabVIEW toolbox can be used to realize the required functions in short time.

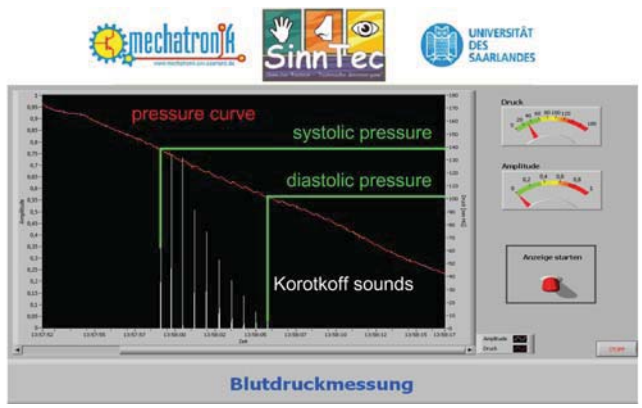

Figure 3. Example of a front-panel in LabVIEW, here showing the signals from pressure sensor and microphone for the blood pressure measurement.

To further simplify the development of programs for specific experiments a Virtual Instrument (VI) was realized, i.e. a single element or function in LabVIEW providing access to the complete functionality of the VenDASys hardware platform. By integrating this element in their own programs the complete communication and internal operation of the hardware/software combination is hidden for students. In this way, they can concentrate on the experiment itself without distraction from the electronics or the data communication.

C. Sensor modules

The system offers two options to connect the sensors with the VenDASys in order to set-up complex experiments. The first option uses standard lab-cables, which are connected individually for the different elements in the experiment. This option is used during the development phase of experiments enabling flexible connections and fast adaptation when errors are made. The second option is the connection of complete sensor modules or even experiments via Sub-D25-connectors, which is used after the development phase is complete in order to provide a fast and correct set-up of experiments. This option is especially useful for classroom experiments, when there is little time for setting up and high dependability is required.

III. BLOOD PRESSURE MONITORING: AN EXAMPLE

To illustrate the use of VenDASys for experiments with students, we will describe a new experiment that was recently realized to convey fundamental knowledge on pressure sensors as well as outlining an everyday application. After discussing the different uses of pressure sensors, e.g. for weather stations or height measurements, to monitor tire pressure etc, we chose a medical application in order to point out that VenDASys cannot only be used in physics and technology but also for other natural sciences like biology and chemistry.

The technical background of the experiment is the blood pressure (BP) measurement based on the widely used concept of Riva-Rocci as depicted in Fig. 4. A cuff is used to apply pressure on the arteries while the physician listens to the so called Korotkoff sounds in the brachial artery at the elbow using a stethoscope. In the experiment a pressure sensor is used for the BP measurement and a microphone - essentially another pressure sensor for dynamic pressure changes - to record the Korotkoff sounds. This emulates the function principle of commercial automatic blood pressure monitors for home use.

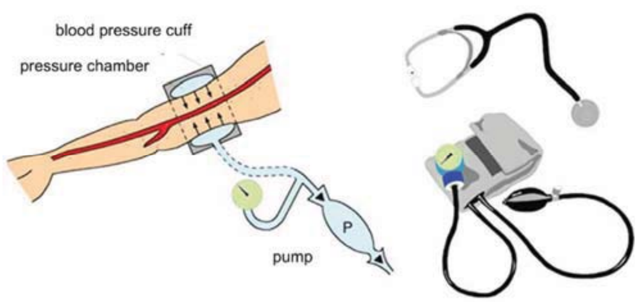

Figure 4. Blood pressure measurement according to Riva-Rocci [7]

In addition, the experiment addresses the function principle of the pressure sensor itself and the necessity to calibrate sensors before use. In order to allow a larger group of students (up to 16) to work, we divided the experiment into four sections or experimental stations as shown in Fig. 5. After explaining the overall goal of the experiments and some background on blood pressure measurement, the first two stations address necessary basic electronics and sensor concepts, i.e. a Wheatstone bridge circuit for evaluating resistive sensors and strain gauges for force, weight or pressure. The third station addresses the calibration of the pressure sensor, while in the fourth and final stage an actual blood pressure measurement is performed using the previously calibrated sensor. All stations make use of the principle of activity-based teaching, so that students have a real hands-on experience and do not only watch a teacher setting up and performing a demonstration experiment. Of course, the necessary equipment is prepared and the students are given a handbook guiding them through the experiment.

In the first three stations, basic VenDASys functions, i.e. power supply and analog measurement, are used; for the final station a dedicated program for recording and displaying the measured data and determining the blood pressure is used (Fig. 3) exemplifying the broad VenDASys spectrum.

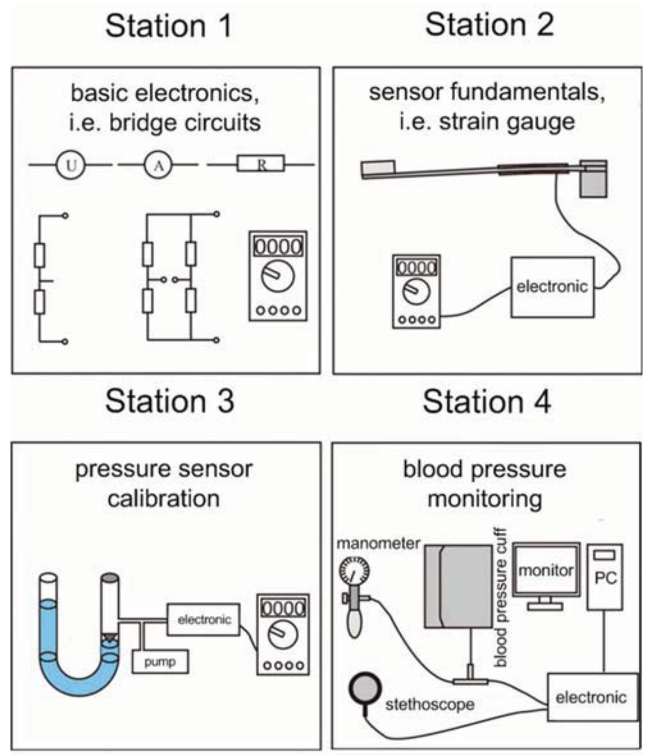

Figure 5. The four experimental stations of the BP monitoring experiment.

A. *Theoretical background*

Historically arterial pressure was measured using the height of a column of mercury to reflect the circulating pressure. Today blood pressure (BP) values are still reported in millimeters of mercury (mmHg), even though modern instruments no longer use mercury. For each heartbeat, BP varies between systolic and diastolic pressures. Systolic pressure is the peak pressure in the arteries occurring near the end of the cardiac cycle when the ventricles are contracting. Diastolic pressure is the minimum pressure in the arteries occurring near the beginning of the cardiac cycle when the ventricles are filled with blood. An example of normal measured values for a resting, healthy adult human is 115 mmHg (approx. 15.3 kPa) systolic and 75 mmHg (approx. 10 kPa) diastolic (written as 115/75 mmHg, and spoken as "one-fifteen over seventy-five") [8].

The most common method for BP monitoring is the indirect measurement according to Riva-Rocci (Fig. 5.), also called the *auscultatory* method (from the Latin for *listening*). In this method, a pressure greater than the systolic pressure is applied using a cuff which collapses the artery. Thus, the blood pressure wave cannot continue in the direction of the hand and no pulse can be felt or heard in the lower arm. The cuff pressure is then slowly reduced and the Korotkoff sounds are recorded. When the pressure falls below the systolic pressure, i.e. when blood just starts to flow in the artery, the turbulent flow creates a "whooshing" or pounding (first Korotkoff sound). The pressure at which this sound is first heard or recorded is the systolic BP. The cuff pressure is further released until the artery is open permanently, i.e. no more sound is heard (fifth Korotkoff sound), at the diastolic arterial pressure [8]. The process is depicted in Fig. 6. The Korotkoff sounds are either manually registered using a stethoscope or automatically using a microphone.

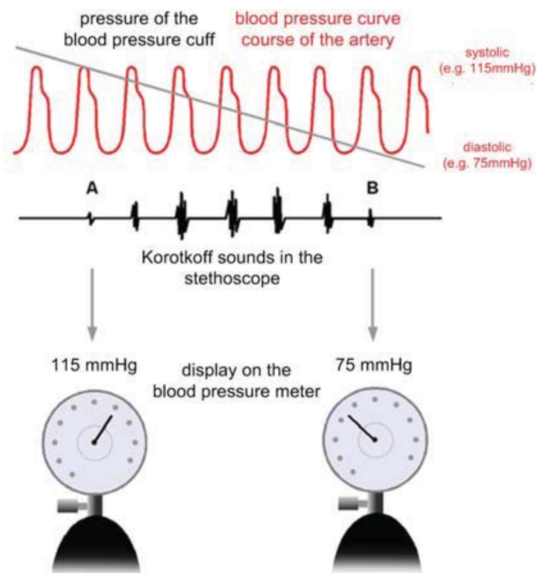

Figure 6. Blood pressure measurement based on Korotkoff sounds [9]

Thus, for BP monitoring two quantities have to be measured using appropriate sensors: the static pressure in the cuff and the Korotkoff sounds in the brachial artery at the elbow. As sound is basically a high frequency pressure fluctuation, both sensors are very similar. The experiment concentrates on the static pressure sensor which is easier to understand, but also requires higher precision. A standard microphone with audio amplifier is used for recording the Korotkoff sounds.

B. Pressure sensor function principle and calibration

Pressure sensors today are commonly manufactured using microtechnologies; they were one of the first mass applications of MEMS. The sensor basically consists of a Si chip with thin membrane and integrated piezo-resistive strain gauges in a bridge configuration (Fig. 7). A pressure difference across the membrane leads to a bending of the membrane and thus an electrical signal. With a vacuum on one side of the membrane by applying a glass cap the absolute pressure can be measured.

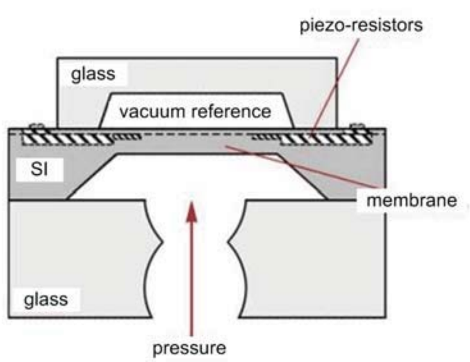

Figure 7. Schematic of a piezo-resistive absolute pressure microsensor [10]

Conversion of the mechanical quantity pressure, i.e. force per area, into an electrical quantity requires several steps. In the first step the pressure is converted into surface tension by the membrane, on which surface zones will exhibit tensile and compressive strain. Piezo resistors convert this strain into resistance changes, which is finally converted to a voltage by the bridge configuration. Since the strain and the resistance changes are small, the output voltage is also small and has to be amplified for recording. Thus, in the experiment stations the function principle of a Wheatstone bridge and strain gauges are addressed as necessary fundamentals for the pressure sensor. To make the pressure sensor, which is only a few mm square in size, more accessible to students we developed a macro model which is used to explain the sensor function principle, Fig. 8.

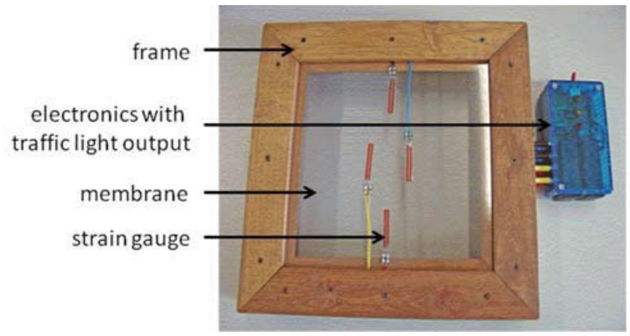

Figure 8. Macro model of a pressure sensor (size approx. 30 cm square). Applying pressure to the membrane results in a simple output (green: low, yellow medium and red high pressure, respectively).

After explaining the function principle students work with a Wheatstone bridge and strain gauges for a weight measurement in the first two experimental stations, respectively. In the third station, a pressure sensor is calibrated using a water (instead of Mercury) column, Fig. 9. The sensitivity of the sensor (in mV/mmHg) is calculated from the measurements of height vs. output voltage and the densities for water and mercury.

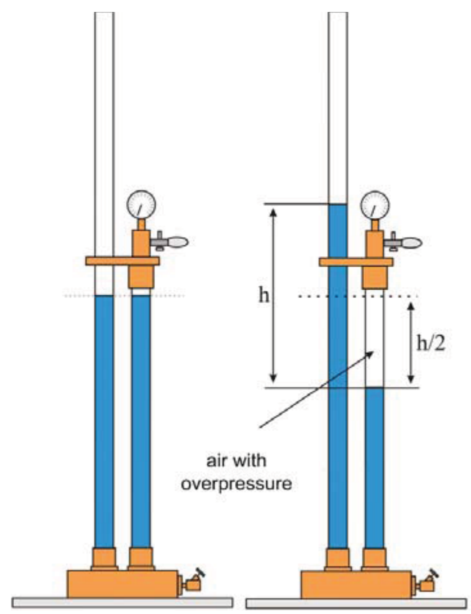

Figure 9. Calibration of the pressure sensor using a water column

C. BP monitoring with the VenDASys experiment

After addressing the scientific and technical fundamentals in the introductory talk and the first three stations students use a designated VenDASys experiment set-up for monitoring their own blood pressure in the final station. At the beginning of the experiment the necessary components are introduced and explained. Fig. 10 shows the microphone with amplifier, the blood pressure cuff with manual pump as parts of the complete experimental set-up. The experiment is set-up by the students themselves based on an instruction guide.

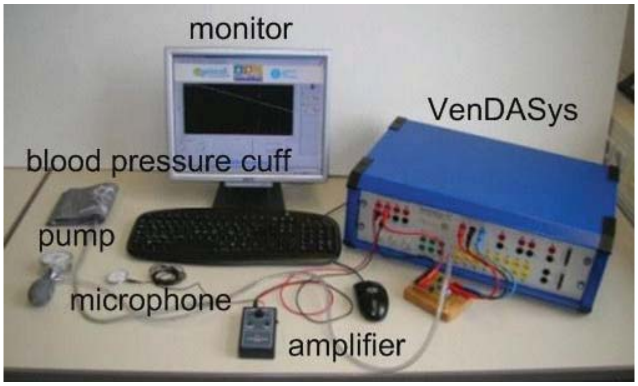

Figure 10. Complete experimental set-up for blood pressure monitoring.

Then, students can either use existing software to run the experiment or, if more time is available, realize their own program for recording and displaying sensor data and extracting the correct blood pressure values using pressure sensitivity obtained by the calibration in station 3. Finally, students take their own blood pressure using the set-up as shown in Fig. 11.

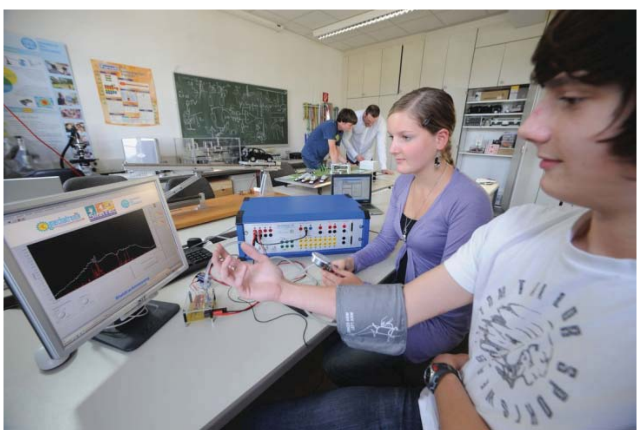

Figure 11. Students measuring their BP after setting up the experiment.

Fig. 3 shows the front panel of the standard LabVIEW software for BP measurement. In the main window, the pressure curve (red) and the signal intensity recorded by the microphone (white) are displayed; in addition analog scales (top right) show the current sensor values. After pressurizing the cuff until no noise is recorded (no reading on the appropriate scale) data recording is started with the button on the bottom right. When the pressure in the cuff is slowly reduced, the diminishing pressure and the Korotkoff sounds are recorded and displayed. From this diagram the systolic (onset of Korotkoff sounds) and diastolic (disappearance of Korotkoff sounds) pressures can be extracted as shown in Fig. 3.

With this experiment, students learn a wide range of different topics from biological fundamentals (blood pressure) to sensor basics (bridge circuits, strain gauge, pressure sensor) to automated evaluation of measurements in technical systems. Apart from function principles they also learn practical application as well as problems in using sensors, e.g. the need for correct calibration. During the experiment, VenDASys helps students with addressing the different stages, simplifying the electronics and allowing students and teachers to focus on the experiment. At the same time, they learn and understand the principles behind an everyday object like an automatic BP monitor thus taking the technology out of its “black box”. Finally, and for our purpose perhaps most important, students are shown that science and technology is fun and that they themselves can realize similar experiments with a minimum of effort, especially using VenDASys as a versatile platform.

D. Evaluation of the experiment with high school students

After the experiment, the participating students were asked to evaluate the experiment in several categories such as *the experiment was fun* using a five point grade scale ranging from *I totally agree* to *I totally disagree* and also the experiment overall on a scale from *excellent* to *awful*. Fig. 12 shows results of this survey for the first time this experiment was used in our learning lab SinnTec on March 25, 2009, by 10 students.

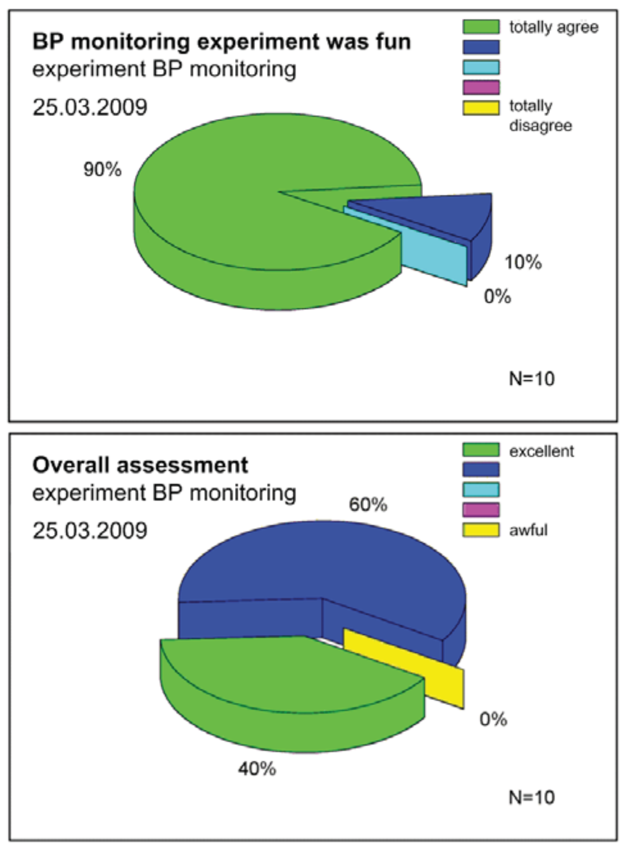

Figure 12. Exemplary evaluation results of the experiment blood pressure monitoring by participating students, 25.03.2009

While the number of students is of course too small for a sound statistical analysis the survey results and also comments by the students are encouraging. While the overall assessment is similar (slightly better) compared to other SinnTec experiments, the agreement in the category *the experiment was fun* is exceptionally high at 90%.

We attribute the higher fun factor of the experiment to two things: (1) the topic with its medical background and every day applicability was probably more attractive for students; (2) the VenDASys, which was used for the first time in a complex experimental setting, allowed students to concentrate more on the experiment and its implications than in other examples, where more effort and focus was required for the required electronics.

IV. Further Experiments

Besides the BP monitoring experiment described in detail above, we are currently developing further experiments, each of which addresses another sensor principle and an application example taken from every day experience. One experiment, implemented by a high school student in an extracurricular project, addresses the automatic identification of different solvents with a gas sensor. The experiment simulates a freight depot, where model carriages are shunted to their respective tracks. Here, VenDASys is used to automate the sequential control as well as the selection of the correct track (Fig. 13).

Figure 13. Experiment freight depot with automatic carriage identification

In addition to these experiments, we are also developing a self-study course on electronics. Using this course students and teachers will have the possibility to independently learn fundamentals of electronic components and basic circuits. In the course, VenDASys is used to replace different expensive components and instruments as well as provide step by step instructions from learning the characteristics of simple components to realizing complete circuits, e.g. for sensor read-out.

V. Conclusion and Outlook

With the approach described in detail above the following educational aspects can be addressed:

VenDASys is based on a strictly modular, open approach, i.e. all hardware interfaces as well as the software codes are fully available for every user. This enables schools and universities to interface existing and to add new experiments simply and cost efficiently - a crucial aspect for most institutions.

During the development and later in the dissemination of the course and the different experiments we are cooperating closely with different school teachers and their students to receive feedback and input. In addition, the input by teachers will be used to ensure that the VenDASys-GUIs fulfill strict didactic requirements to allow intuitive use by students and teachers alike. In the first experiments implemented jointly with teachers a didactic scheme will be designed to be used henceforth.

Synergy effects are created by exchanging experiments via our web-site [11]: mechanical designs, interface electronics and software will be made available for download allowing fast growth of the common experimental pool. Before uploading any element it is checked and, if needed, software is adapted to fit into the didactic scheme allowing intuitive use. In addition, the website will provide user support, e.g. with discussion forum and an FAQ (Frequently Asked Questions) section.

While microsensors and MEMS are our primary concern, we want to expand the application of VenDASys to other fields in engineering and science to make full use of its potential. Besides biology/medicine, as demonstrated with the BP experiment, we think that also chemistry provides high potential for VenDASys application, for example monitoring of reactions or even experiments on bio-fuel generation.

Currently, the system is extensively tested together with pilot users, the results will be continuously reviewed for further improvement. It is clearly not our goal to compete with commercial products offering highly sophisticated systems specifically for the classroom. Instead, our focus is on a system which can be used by students individually and in teams when dealing with technical and scientific subjects in general and MEMS topics or sensor applications in particular.

Acknowledgment

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Virtual flute: electronic device that uses virtual reality to teach how to play a flute

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Abstract—**In this paper is described the process that should be done for developing a interactive tool for supporting the musical learning specifically on how to play a flute on its basics. This device has two main stages, the first one takes over the teaching part and guidance to the student by an software interface and the second one has the responsibility of captured how is being played the flute using a pressure sensor and reflective transducers. With this example is expected to contribute in research and implementation of teaching devices around the world.**

Keywords-acoustoelectric devices; computer applications; learning systems; music; technological innovation; virtual reality

I. INTRODUCTION

Nowadays, the learning process needs a complement tool which could make it more efficient, enjoyable and accessible for every person who wanted to acquire knowledge in certain area. The virtual reality helps in making the education more contemporary it generates in young people the desire to research and learn about different stuff.

Many of the increasing challenges are arising from the emerging generation of new learners who are far more proficient with VR and other computer applications. The trend in professional society is also changing based on new learning tools and modes. Recently, virtual worlds have become an important part of teaching and training, transforming the way people work and learn. As technology allows more and more content to be virtual, so improves the possibility of better learner engagement [1].

Along with the device an educational pedagogy is integrated it ensures the success of student learning through implementing constructivist pedagogy instead of the traditional way of education giving a greater and more representative role to the student, recognizing that he/she is the main actor in the learning process.

The significant changes that today's students bring with them when they start their post-secondary education creates an urgent call to understanding the different ways they learn and therefore, to change the ways institutions educate them. But it is time not only to radically change the way teaching takes place, but also, to redesign curriculum, graduation processes, evaluation methods, infrastructure needs, and so on [1].

Making the teaching more interactive allows the student to learn on his/her own way, especially in music areas there are some difficulties for students who are subjected to inappropriate patterns of study. The skills and abilities could be different from each other.

At the same time, it is seen in our society the need to develop teaching tools and technology of interactive models more efficient and attractive, making the learning process more enjoyable. The non Immersive virtual reality offers in this case, an option where the interesting and useful interactive educational simulators are an innovative way of presenting to a student the information that is required to learn, giving the opportunity to be evaluated and followed throughout this process, leaving behind the traditional teaching, instead implemented a constructivist pedagogy.

Virtual reality is not a representation of a specific experience in the actual world, but it is a new mode of experience where various sensory and imaginary experiences are fused. This is not simply a way to understand and effectively access the actual world, but it is a driving force that carries forth the human activities and it is an independent reality that gets feedback from those activities. Users can experience virtual reality that is unrelated to the physical world [2].

Therefore it was decided to develop the "Virtual flute" in which an electronic device with software has the purpose to accompany and guide the student through the process of learning how to play a flute. The dynamic of the device has three stages a first one that gives all the instructions to the user, a second one where the hardware senses the note and finally a feedback of these data to the computer.

The following document shows the systems implemented for the realization of the device. Will present all needed to understand the functioning of the hardware, the progress made with their results and applications where the device would operate in an optimal way.

II. VIRTUAL REALITY

VR is a kind of technology that enables users to get sensory experiences on real things in a similar way to the one that they use when they interface normally with physical world. Such experience is only simulated; it does not mean a new experience has occurred. In other words, virtual reality is nothing but an artificial reality which is a substitute for natural reality that is felt in the actual world [2].

This device implements non immersive (desktop) virtual reality which offers less real sense than immersive virtual reality, but when it is accompanied by hardware it permits the possibility to the student of being in contact with the instrument that needs to play. The feeling is much more real than if they only see the information in a computer. In addition the feedback from the captured data from the sensors allow for seamless interaction between the student and this educational tool.

To stimulate creativity and productivity, the virtual experience must be credible. The "reality" must both react to the human participants in physically and perceptually appropriate ways, and conform to their personal cognitive representations of the microworld in which they are engrossed [3].

In the music field when someone wants to learn how to play an instrument is important to use a hardware which simulates the musical instrument and the student could be in contact with an object similar to the real one and be prepared for when he/she needs to play a real instrument.

New technologies related to computer music make it possible to not only create new types of music by ourselves, but also to learn conventional music more easily [4].

The principle purpose of the "Virtual Flute" is to facilitate the learning process on how to play a flute, offering a new way to practice and study the basic musical notes. Using this tool the student could practice whenever he/she wants as fast as each one decides, this allows a more enjoyable learning process.

Nijholt, thinks that technology can play two major roles in music education. Firstly, technology can supplement and support skills of parents and teachers essential to the musical development of children that are becoming rare or underdeveloped or for which time lacks. Note that such technology should not replace those skills but rather be accompanied by initiatives that encourage the development of such skills. Secondly, technology can make music education more efficient by taking time consuming, less creative, essentially 'practice' activities and offering them in a context in which students can master them individually, leaving more time for teachers to focus on the communicative/creative skills of music [5].

Therefore is seen the important mission that has the technology to develop different methods of participation in music and its processes: learning and practice.

III. METHODOLOGY

Two methodologies were implemented the first one which handled the development of theoretical research and the second which designs the interactive tool.

The research methodology was based in theories from Mendez [6], Lerma [7], Tamayo [8] and Cerda [9].

TABLE I. RESEARCH METHODOLOGY IMPLEMENTED

.Stages
Topic description
Problematic
Objectives
Justification
Similar examples
Definition of the methodology for developing the tool

During the topic description stage was determined the interactive tool scope and its limits then was seen and defined the "what for" of the learning device and clarified all the functions that should have the virtual reality tool after that was determined the motivations for the development of the device and was made a research about existing research and development about similar projects, finally was determined how would be developed the interactive tool

TABLE II. METHODOLOGY DESIGN FOR THE ELECTRONIC DEVICE

Stages
Planning
Requirements
Analysis
Devices design
Construction
Tests

During the planning stage was defined what will be done, the list of activities, team work, materials that constitute the device and the required tools then was set out the different characteristics that the device must have. After that was analyzed the requirements and the possible ways to develop the interactive tool, building a model to determine the physical structure and technology used and were made the sketches, proposals for structural design and performance. Then was made the flute's implementation with the sensors, signal conditioning and data transmission finally were made some tests of the flute's performance including the software.

IV. VIRTUAL FLUTE

A. Materials

Virtual reality's central objective is to place the participant in a virtual environment that gives the participant a feeling of "being there." This requires linking the human perceptual and muscle systems with the "virtual environment." A VR system consists of three types of hardware: 1) sensors, 2) effectors and 3) the reality simulators. [10]

The following are the most important electronic components that have the interactive tool:

The sensor Mpxv 4006 Freescale is used to measure the flow of air from the blow that leads the user when he or she play a music note on the electronic instrument. It works from 0 to 6 kPa, and is responsible for allocating a voltage value to the air pressure with a reference value of 4.8V for the maximum pressure to 0.17V for the minimum.

To identify the parameter of average pressure when the flute is played the right way were taken different samples of people with knowledge about how to play the flute correctly, noting that the results were close to a range of values specified in the driver program to analyze and compare each moment of execution.

The operating characteristics of this pressure sensor are: the pressure range is between 0 and 6kPa or what is the same 0 to 0.87 psi. The current supply could be from 7mA to 10mA. The operating temperature is between -40°C and 125 °C and the response time is 1mS.

The above characteristics determine the ease of using a device like this, its maneuverability in the prototype and its operating qualities that make it an excellent mechanism for implementing within the device.

For sensing the position of the fingers on the virtual flute are used eight reflective sensors. The Reflective Optical Sensor, CNY70 has a compact construction where the emitting light source and the detector are arranged in the same direction to sense the presence of an object by using the reflective IR beam from the object. The operating wavelength is 950 nm. The detector consists of a phototransistor [11].

Fig. 1 shows the construction of the sensor and its operation, this sensor is implemented in each hole of the flute to identify when it is being covered by a finger or not.

At the moment the finger is positioned over the hole, there is a reflective surface that makes the role of the medium of reflection for the infrared beam emitted by the diode, making driving transistor receiver.

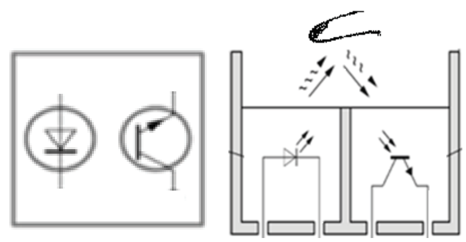

Figure 1. CNY 70 diagram

B. Flute Design

Fig. 2 shows one of the implemented prototypes of housing, which allows opening the main tube, to give the possibility to put the electronics needed to operate. It was made of wood with an original design made particularly for this application.

Figure 2. First designed flute

Fig. 3 shows another implemented prototype of housing, which is a typical flute with a little box which has the electronic components; this model permits an easier and more real way to play the flute.

Figure 3. Last designed flute

The following table shows the values of voltage measured at the output of the pressure sensor, captured in several tests to persons who knows the art of playing the flute, these data are the parameters used to design an algorithm that discriminates between a note that is played the right way and other that is not.

TABLE III. | VOLTAGE AT THE OUTPUT OF THE SENSOR

Student	Voltage at the output of the sensor
1	2.01
2	2.23
3	2.16
4	2.34
5	2.37
6	2.26
7	2.27
8	2.31
9	2.13
10	2.11
11	2.13
12	2.46
13	2.54
14	2.27

The analysis of the results, generates a voltage range in which the note is being well executed, which corresponds to approximately 0.326 psi or 22.2x10 ^ -3 Atm or 2.25 KPa.

V. Results

The main result was the successful implementation of hardware device that captures the basic musical notes which are being played on a flute and transmitted to the computer, where the interaction is consistent and efficient.

The combination of music instruction, the sensors and the communication with the computer, generated a electronic device in which has an application of software that was developed in Java, Netbeans, and it provides the necessary information to the student to learn how to play the basic notes on a flute and gives the opportunity to practice and be evaluated, according to this the computer sends data to an electronic circuit for identifying what note should be captured by a PIC microcontroller, the data are captured from the sensors of the hardware part (air pressure and fingers position) are analyzed and returned data to the software which provides a correction or an acceptance of performance, thus completing a cycle of information and feedback aimed at the understanding and successful learning.

The software makes the instruction to the user, displaying the correct way to play a flute, when the user has reviewed this information with the speed that he/ she wants and how often he/she desired necessary then they could choose the appropriate type of test to perform, creating a kind of constructivist pedagogy which offers to the student the necessary tools for the learning process.

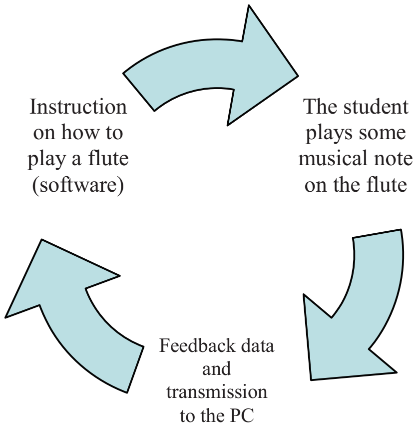

Figure 4. System Dynamic

When the activity is chosen, data are sent to a PIC microcontroller, which identifies the note that must be play by the user in the following seconds, then analyzes the input of the position of the fingers by the digital inputs of microcontroller and the air pressure exerted by the blow of the user, using analogue digital converter from the same integrated circuit to be compared with the expected feedback and response to a computer (USB communication), specifically to the software in Netbeans, indicating the student qualities or their shortcomings in implementation.

Thus, it generates a dynamic conducive to the goal of teaching the correct way to play a flute.

The following figures (*Fig. 5 and Fig. 6)* are samples of the graphical environment of the software application developed for this interactive tool, because the device is primarily designed for children, the graphics are very colorful and animated in order to attract attention.

Figure 5. Software designed

Figure 6. Software designed

VI. DISCUSSION

The learning and / or musical training are complex for many students because they do not have enough tools, for example they do not have someone or something that continually motivate and guide them for training in musical performance as a contemporary art. Also there are people who are subjected to inappropriate patterns of study for their skills and abilities in the learning process in this area. These factors cause dissatisfaction in a specific group that wants to work on their artistic abilities.

this paper presents a device able to sense the musical notes that are played by a user, with software that guides a user interested in learning the art of playing a flute, it noted the importance of implementing educational tools, which makes more efficient and effective the learning process, demonstrating the importance of electronic applications in low and high impact exploration in different aspects, as in this case in the arts and music pedagogy.

An academic impact was generated; this project brings improvements in the research and implementation of such devices and at the same time with these devices provides an innovative way of teaching that makes an easier and more interesting learning process.

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An adaptive Multi-Agent based Architecture for Engineering Education

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Abstract— **This paper proposes an agent-based adaptive Architecture to extend *Moodle* in order to support instructional decisions and adaptive behaviour in engineering education. The paper describes the characteristics, functions, and interactions of the agents which take part in each module of the adaptive architecture. In addition, we describe the origin and function of ToDei, the proposed intelligent agent for Instructional Decisions Making. This agent is in charge of collecting information generated by the rest of agents and deciding what is best for the final users, tutors and students, taking into account their attitudes towards the learning environment.**

Keywords: *Intelligent agents; adaptive educational systems; ntelligent systems; user modelling; tutor modelling*

I. Introduction

One of the challenges of engineering education is to tackle with complex learning experiences which in many cases include the use of a diversity of tools and environments, drill and practice processes, virtual laboratories, etc. In this context, the use of adaptive content has been proven to be an important contribution to facilitate learning [1][9][10], provided as an extension of a given learning architecture. From all the VLE open sources available in the web, Moodle is the most widespread and used around the world. Currently, there are 56357 sites from 210 countries registered as Moddle[1] sites. They are supported by a development community that provides current updates and support. Due to the previously mentioned services and to the portability and modularity that characterizes this community, it has been easy to present a proposal with an adaptive focus that contributes to the growth and exponential development of the VLE open source with tendency to an Adaptative Educational System (AES).

The Moodle approach is based on three main components: the professor, the classroom in which the educational process is given, and the students. They work together in the following way:

The professor looks for and produces all the information necessary for the course development. He/she organizes it in weekly blocks or in thematic blocks and enters the topic orientation, the supporting resources and tools (files, documents, videos, audio, etc.), and the activities that must be developed by the student.

The student is in charge of developing the proposed activities, downloading or checking the resources and interacting with his/her partners according to the orientations received by the professor. The teaching-learning process is developed in the classroom, and the information generated here is stored in a relational data base that is fed and accessed through the user interface. The Moodle's structure allows providing facilities in order to give each one of the student's different resources and activities, to give advice to students, and to facilitate the interaction between students to students, students to professors and vice - versa. If there is not information related to the user preferences, the navigation sequence, the document evaluation, and the knowledge level, the teaching-learning process will be developed in a general way for all the members of a course. And a personalized service will not be offered to each student.

One alternative to such problems is to focus Moodle on students' needs, trying to adapt this system to each one of the students and training them according to their learning styles as well as adjusting the system to the students' needs. For this reason, a structure that allows Moodle to be adaptive is necessary.

The proposed architecture is based on the main areas of adaptation defined in [2], providing presentation and navigation adaptation using intelligent agents associated to different modules in Moodle. This multi-agent methodology has recently appeared as a good companion of adaptive distributed educational systems. User adaptation using intelligent agents has been developed using several approaches. For instance as users' self test, like in [3] that provides an adaptive testing tool to fit the student's level of

[1] Moodle.org. http://moodle.org/sites

knowledge, where questions are generated automatically; or integrating agents in VLE as in [10] where educational content is made available by means of a process of re-categorization carried out using intelligent agents within the VLE.

Furthermore, it is considered a multi-agent structure that needs to be easily applied to the modular architecture of Moodle and offers a dynamic adaptation through learning. This learning is developed by each one of the agents that intervene in each component .

II. Adaptative Logical Architecture Proposed for Moodle

The proposed architecture of AES for *Moodle*, has four principal modules: tutor module, student module, user interface module, and knowledge base.

Each of the first three has an intelligent agent that performs tasks for each module. For communication and interaction among agents of each component, the agent called ToDei has been defined. Its goal is to take the information of each module and decide the best method of instruction for the final user. In the knowledge base module, the development of one or more agents can be considered, depending on the way the information is structured (taxonomy or ontology, for example). For the present case, no agent has been defined in this module since its basic functions will be performed by the ToDei agent.

For each agent, the principal functions are defined. Therefore, the one who works on the tutor module has didactic-pedagogical functions and tutor modelling, and the student module carries out the creation of student models and information updating. The user interface module (student-tutor) determines the most appropriate interface for each user based on the hardware and software used for the connection. The ToDei agent communicates and determines the best instruction for the user.

The components of the different modules proposed for AES are based on research based on an analysis of available information on the Moodle virtual platform, which permits definition of the necessary task adaptation to acquire an adaptive approach. As stated clearly before, the components and intelligent agents that will intervene in an adaptive architecture, using the Moodle virtual platform as a base, are shown.

A. Tutor Model

The instructor, who is an actor in (traditional) Moodle, becomes a component in this type of architecture, in which the best way to make information available to students is identified. This function is performed by an intelligent agent, which will make decisions according to various variables that could be considered to provide knowledge to students.

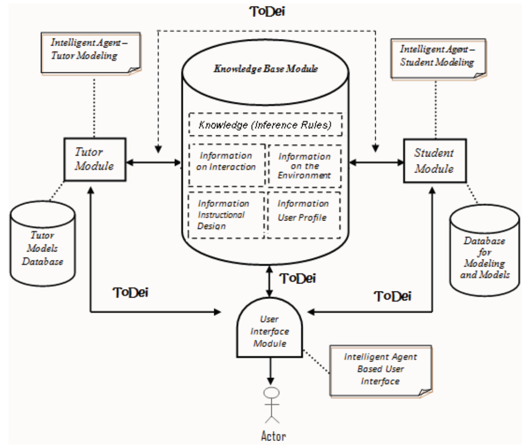


Figure 1. Moodle’s Adaptative Logical Arquitecture

This activity is supported by the instructional design and the different versions of the material made by instructors [8]. The different tutor models generated by the agent are stored in this module. At the same time, this agent is in contact with the knowledge base module in order to retrieve and store information. The intelligent agent, which is associated with this module, is the intelligent agent for tutor modeling that must perform the following functions:

- Pedagogical-didactical (teaching style)
- Tutor modeling (implementation of contents)

Intelligent Agent for Tutor Modeling

The tutor modeling agent has been designed to perform the following functions:

- *Didactical-Pedagogical*. Each instructor has his/her own style to encourage learning among students, which is perceived differently by each student. This situation is what the intelligent agent attempts to simulate and learn in order to guide students in what and how to learn.
  According to students’ acceptance and response to a particular style, the agent will be able to classify what teaching form is the most accepted by a particular student profile. Thus, once the agent has learned, it can choose the most appropriate style for each user based on his or her profile.
- *Tutor Modeling.* The main feature of this function is the analysis of the organization and implementation of contents according to the experience that the agent has acquired. This process will begin with a modeling that gathers information on activities and resources proposed to students and on their success rate. Based on this experience, the agent will learn the best way to implement contents.

After analyzing this information, some tutor models, which can be applied to determined student models, can be defined. Tutor models may vary depending on the level of learning and experience acquired by the agent. This will permit the definition of more concrete models that can be best adjusted to a particular type of student.

Considering the classification made by [4] and [5] regarding the structure of an agent, the tutor modelling agent can be categorized within the *informed agents that maintain a design of the world* due to a) the constant updating of the environment in which this agent operates, b) the updating that must be done in the tutor modelling, and c) the decisions about what content should be offered to the student.

The use case according to the task that this agent must complete is shown in Figure 2:

B. Knowledge Base Module

This module has the initial knowledge of the system, expressed in statements of general validity as like as inference rules or probability distributions [7], these are used by the agent to infer a conclusion or new knowledge, used various information sources such as a) student's personal data, b) interaction data, c) environment data, and d) information on

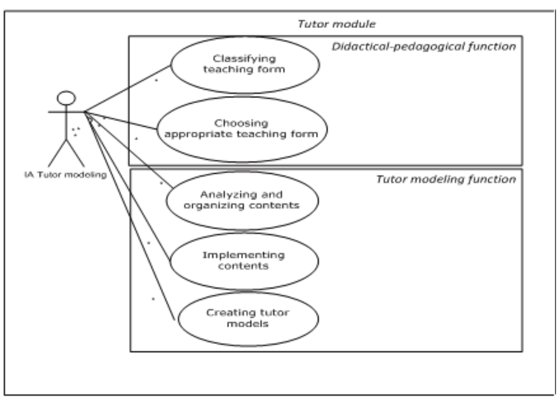


Figure 2. Use Case of Tutor Model

instructional design. This Knowledge can be organized into different structures such as taxonomies, conceptual maps, thesaurus, and even ontologies.

C. Student Module

Regarding AESs, students generate the underlying information for adaptation. For this reason, in an adaptive architecture, this actor turns into an independent module in which, based on the students' characteristics, needs and preferences [6], different models are generated.

For this module, the following use cases can be identified:

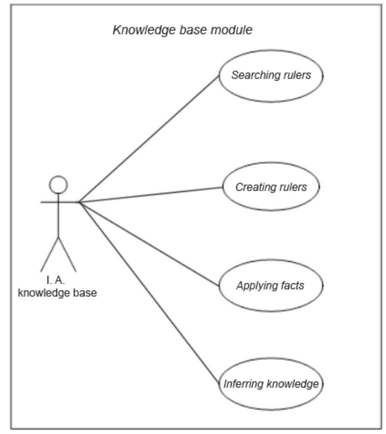


Figure 3. Use Case Knowledge Base Module

Intelligent Agent for Student Modeling

The agent for student modeling performs some functions in this module. These functions include:

- Creation of Student Models. Creation of student models based on a previous model, in which explicit and implicit variables are defined and include navigation environments, learning styles, learning levels, cooperation levels and interaction levels. Once models have been created, the agent will be able to categorize the different student profiles according to the model with which they share similarities. This will favor a more significant learning experience.
- Information Update. This function collects information about the student from the moment the student accesses the system. This information is updated by the agent, which is in charge of monitoring various activities, routes, and actions of the student in the system. After comparing some characteristics that students accumulate in their profiles, and if necessary, the agent will be able to change the model to which the user was assigned and determine the progress of the user in the system.

This agent interacts with the knowledge base through the instructional decision making agent (ToDei), from which data of each profile are retrieved and saved once the student has been identified in the system or when the student exits the system.

Returning to the classification made by [4], the agent for tutor modelling can be classified within the *informed agents that maintain a design of the world* due to a) the constant updating of the environment in which this agent operates, b) the updating that must be made in the student modelling, and c) the categorization of student profiles regarding the models that were created.

The use case diagram for this agent is shown below:

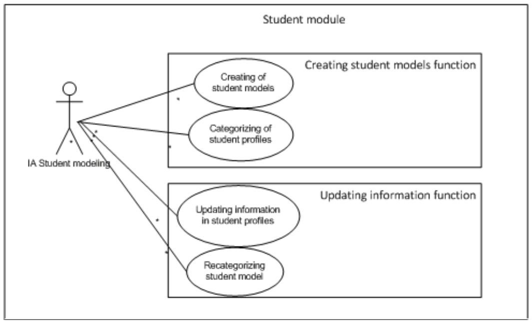


Figure 4. Use Case Studen Module

D. Interface Module for Users

This is the component that shows all the information to the students, trying to capture their attention and keeping them motivated, through redaction of messages type "Inverted Pyramids" [11]. In this module, we identify characteristics such as the type of browser used, type of device used for access, and the available connections.

Intelligent agent for user interface

The objective of this agent is to determine the best interface to be offered to each user based on the hardware and software used for the connection.

The means of connection, the software, and the equipment used are different for each user and for this reason each has different presentation needs. For example, if a student accesses the system from a cell phone, he would only need the most necessary files, but if a student accesses from a carry-on computer with a good bandwidth, he would be able to watch videos and animated films and listen to audio files.

The intelligent agent for user interface should learn these conditions and determine the most appropriate type of system interface for each one. This learning can be acquired when students can interact with the offered interface and when the identification is accepted or denied. This will help classify it as appropriate or inappropriate.

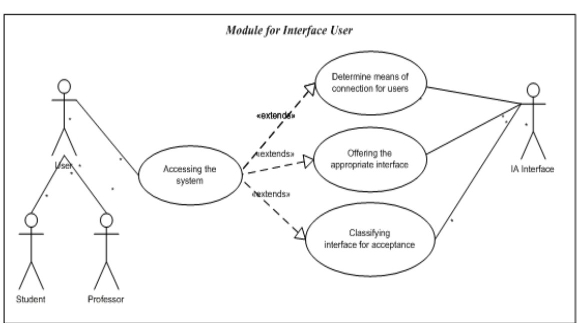


Figure 5. Use Case User Interface Module

Continuing with what [4] stated, this agent has been categorized inside the *informed agents that maintain a design of the world*, since the constant updates from the environment that surrounds it demand different answers depending on each case. For example, it must be able to recognize if a user accesses from a PALM and then accesses from a PC the same day.

The use case diagram that corresponds to this agent is presented below.

E. Intelligent Agent for making instructional decisions (ToDei)

The adaptive architecture that has been proposed is a dynamic structure and multi-agent that allows learning, communication, and independence of each component of the system. In all the components there are agents that facilitate the execution of the process and a particular defined process, but in order to fulfil the requirement of offering the use of the adaptive effect, the communication and interaction of all the components of the architecture are necessary. Consequently, the intelligent agent ToDei is used.

The objective of this intelligent agent is to fulfil these functions as well as to transmit the content to the user. Furthermore, considering the characteristics and greatest needs, it decides the best way to offer information generated in this process.

ToDei receives information through the module for user interface, specifically the one generated by the agent for interface. It is the first to have contact with the user because it communicates with the module for students where the information regarding the profile (stored in the knowledge basis) and the model student (stored in the module for students) are restored. They are then sent to the module for the tutor where, according to the tutor model assigned for the model student, the most appropriate instructional design is offered. Finally, ToDei displays the results of this process to the user. At this stage, the intelligent agent chooses how to show through the interface the content generated based on the style best suited to the learning process of the student.

As observed, ToDei is the only agent present in this architecture which has the function of restoring, transmitting, and sending information through the different modules of the system. Consequently, according to [4] and [5], it has been categorized as an *informed agent that maintains a design of the world* since its function of interacting with all the components of the system forces it to update its internal state based on constant changes of the environment.

Structurally, the intelligent agents are formed by sensors, effectors, states, and the environment [5]. The elements regarding the ToDei agent are described in the following paragraphs.

- ***Sensors:*** These are the parts of the agent in charge of detecting changes, requests, and requirements needed by the environment. Furthermore, they become the source of information and the means of updating the states stored by the agent. For example, if the environment of the agent shows that the user has accessed the system, the sensor will detect this change and send it to a state where the action-reaction rules will be applied. This will determine the student model to which the user belongs and will show through the effectors the appropriate content for this model.
- ***Effectors:*** Their function is to take the final actions to be applied to the agent environment, which were perceived by the sensors, allocated in a state, and responded to by the action-reaction rules.
- ***States:*** They are the changes that have been detected by sensors and the answers shown through the effectors of the agent according to its corresponding environment. These are stored in such a way that they allow learning from the agent, keeping for example all the actions taken according to certain perceptions and their effect on the environment. The states are part of the memory of the agent.
- ***Environment:*** It is the environment designed for the agent in which the agent acts and operates. Regarding ToDei, the environment corresponds to the interconnections of the system components.

In this proposal, ToDei has different inputs which are derived from the modules: user interface, students, knowledge basis, and tutor. They generate communication and reception of information through the agents that interact inside each module. The changes generated by such agents are received through the sensors of the ToDei agent; they are processed in the different action-reaction rules (rules of inference) of the agent. Finally, the resulting actions are sent through the effectors to the components that have generated the environment inputs of ToDei and in the same way are stored in the agent memory (states) for its self-learning.

The structure and the process carried out in ToDei are illustrated in the following chart

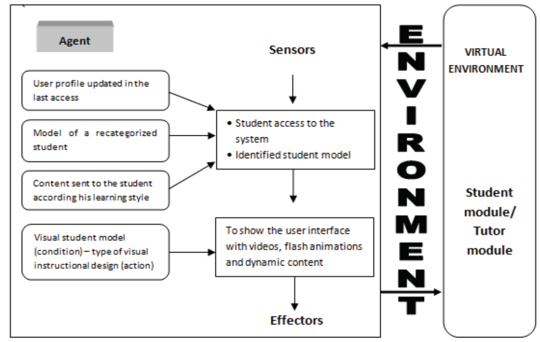
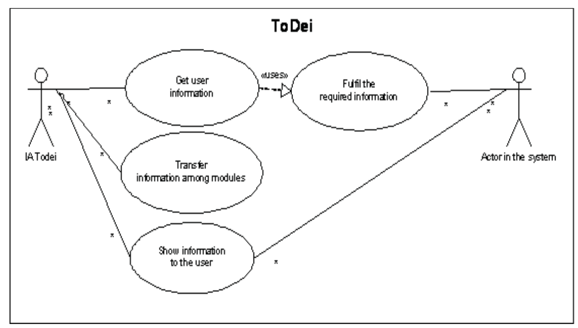


Figure 6. Example of the Structure of ToDei Intelligent Agent

The following use case diagram shows the ToDei process in the system that has been determined for this agent:

Figure 7. Use Case Diagram for ToDei Intelligent Agent

III. CONCLUSIONS



Moodle contain basic information from tutors, students and contents; but no store the interactions path from the different actors. This aspect can be improved by including intelligent components, thus providing a personalized teaching-learning process.

The definition and implementation of intelligent agents in the components of a platform for a Moodle virtual platform do not imply the disappearance of the main actors: professor and student. On the contrary, this platform is a support that helps to reduce the teachers` workload and permits them to focus their efforts on creating good relationships with students to achieve success in learning.

Although they have the same structures, each one of the proposed agents is functionally different but depends on the module on which it is operating. The ToDei agent constitutes the main component inside this architecture since it allows visualization of the adaptive effect generated by the interaction of the components.

IV. FUTURE PROJECTS

Currently, the user model and part of the *ToDei* agent are being developed:

1. The agent which belongs to the student module performs the following functions:
   - Creates student models based on a previous model.
   - Categorizes student profiles.
   - Monitors students while they interact with the platform.
   - Updates student information.
2. The *Todei* agent will present the information according to the categorization of the student profile

Once these components are developed, the construction of any modules that involves the definition of intelligent agents can be achieved. To carry out this, it is necessary to determine the learning type best suited to the available information and to each of the works to be developed. Also is important to consider in the development of each of the modules, the application of usability standards.

In the tutor model when instructional design is defined some mechanisms have to be found to maintain the student investigative spirit, in order to not create any dependency with resources shown by the SAE

ACKNOWLEDGMENT

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Session 01G Area 3: First Year Courses and Programs

On Freshman Training of Engineering Students by Projects and DIY Activities

Li, Yamin; Qian, Jinwu; Wang, Xiaojing
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Assessment of the learning competence of mathematics for first-years of the Computer Science degree

Conejero, Alberto; Juan-Hughet, Jordi; Más, Jorge; Morillas, Samuel; Vendrell, Eduardo
Technical University of Valencia-UPV (Spain)

Analysis of the results of four years of research and application of a student-centered system based on the ECTS to first-year students in order to improve their performance in the subject AC-I

Gutiérrez, Juana M.; Álvarez-Vellisco, Antonio; Bonache, Jorge; Cousido,Carmen; Hernández, Wilmar; Jiménez-Trillo, Juan; Labrador, Manuel; Palmero, Javier
Technical University of Madrid-UPM (Spain)

A Concept Map Approach for Introduction to Computer Engineering Course Curriculum

Cagiltay, Nergiz; Tokdemir, Gul
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On Freshman Training of Engineering Students by Projects and DIY Activities

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***Abstract*- Engineering students begin their first year with fundamental science and pre-technology courses which give little knowledge about engineering. As a consequence, some of the freshmen have no idea about engineering, and are lack of objective and interest in engineering. This paper presents how to help the freshmen have a general idea of engineering and an overall understanding of what they are going to study. One project activity outside curriculum in a LEGO lab and two outside-classroom DIY activity cases are presented. After three years practice, students had more interest and passion in engineering and showed their talents.**

Keywords-freshmen training, research-orientated education, engineering DIY activity

The work of this paper is sponsored by the Educational Quality Program from Shanghai Education Committee.

I. INTRODUCTION

Sino European School of Technology at Shanghai University (UTSEUS) was established in 2006, cooperating by Shanghai University (SHU) and University of Technology (UT) network in France. There are three programs in UTSEUS, for Bachelor, Master and Engineer Diploma, as shown in Fig. 1[1].

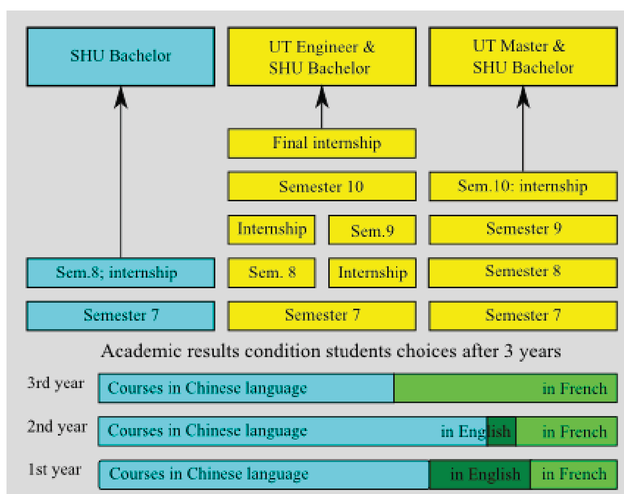


Figure 1. Three degree and diploma programs in UTSEUS

In the program of engineer, students enrolled to Shanghai University first study three years in China, and then they takes other two and half years study in France. After totally five and half years, students get both bachelor degree and engineer diploma if they are qualified to all requirements.

Usually， students begin their first year with fundamental science and pre-technology courses which give little knowledge about engineering. As a consequence of this arrangement, some of the freshmen have no general idea with what engineering is at the beginning of the university study. This leads to the engineering freshmen lack of objective and interest when they are taking fundamental science and pre-technology courses [2].

In term of this, authors of this paper did some work to help freshmen have a general idea of engineering, and make them easier to have an overall understanding of what they are going to study in university, which technology courses they need to master and how those courses are applied to their study.

To achieve this object and get freshmen understood the implicit objectives of further learning, introducing preliminary engineering courses inside or outside classroom is of vital importance. Besides, it contributes to the success of some freshmen and brings them more interest in engineering major.

In this paper one project activity outside curriculum in a LEGO lab and two outside-classroom DIY activity cases are presented. Many students showed their talents on engineering.

II. Project Activity Outside Curriculum in the LEGO Lab

This activity is a kind of project based training with LEGO robot bricks. Freshmen are encouraged to join this activity after class. The LEGO robot lab we have has more than 20 sets of LEGO NXT bricks. Usually every semester 30 students of 10 groups take part in this activity.

The idea of this outside classroom activity is described in detail in Fig. 2.

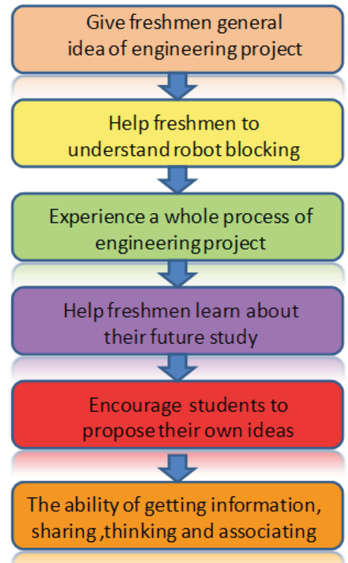


Figure 2. Idea of LEGO Robot Bricks Activity

A. *Give the general idea of engineering project*

To give freshmen the general idea of engineering, teachers usually show a whole process of engineering projects design to students, explaining every step of design. Taking the process of designing a robot vehicle for example:

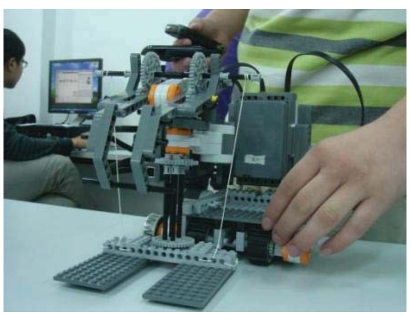
- The first step is to understand and investigate the project you are going to do, then propose several ideas and analysis using Mind Storm and Value Analysis methods, etc.
- The second step is to design the structure of the vehicle using the theory of mechanic, material science, sensor technology and so on.
- The third step is to control the robot vehicle. In order to do this, automatic control Principle, C++ language, algorithm, circuit principle and electrics are probably involved in the design.
- The fourth step is to test and adjust, using testing and measuring technology.
- The last step is to present their work, communicate with each other and make some improvements.

By this activity, freshmen have had a general idea of engineering project and which courses they will learn in their following semesters. The most important is that they know which kinds of technologies are widely used in engineering. Compared with the students who have no idea with technology courses, they are of more objective and positive to engineering major, and are tend to combine theory and practice together.

B. Help freshmen to understand robot blocking

LEGO robot is a modularize robot produced by LEGO company from Denmark. This kind of robot is composed by several modules, such as microcontroller modules with three input ports and four output ports, motor modules with ports can be connected with microcontroller by cables and sensor modules like sound sensors, vision sensors, compasses and various mechanical parts. Regarding to the mechanical part, there are gears, wheels, shafts and pins in different sizes as well as gimbals (Fig 3.).

Besides, there are several expanded interfaces, which allow LEGO robot to be connected with the sensors from other companies, for example, Hitechnic, Mindsensors.



(a)

(b)

Figure 3. Build Robots with LEGO Robot Modules

The advantage of this kind of robot is modularized, and the students could experience that by using LEGO robots with fun. If the freshmen have some ideas, they can build the robot and try their new ideas with modularized LEGO robots immediately, without spending a long time to manufacture the mechanical parts. And a useful mechanism structure can be reused, from project A to project B.

The software used for LEGO robots are also modularized, such as ROBOLAB released by American National Instrument. It is a kind of software which is a simple version of Labview. It is easy for students to begin programming, and to enjoy the convenience which modularization brings to them.

C. Experience a whole process of engineering project by designing a robot using LEGO NXT bricks

It is a necessary activity to guide freshmen to experience a whole process of engineering project. A Chinese proverb say: Tell me and I forget. Show me and I remember. Involve me and I understand [3]. In order to do this, in LEGO lab, teachers assign a target that freshmen should achieve by LEGO robots. Freshmen are divided into groups by three or four persons. They'll carry out the completely procedure of an engineering project.

D. Help freshmen learn about what they are going to study in technology courses

In the steps of structure design and control system design, the freshmen need plenty of knowledge about Mechanics, Material Science, and sensor technology and so on. However, the freshmen may know little knowledge of these domains, as they have no experience of engineering projects previously.

With the activity in LEGO lab, students could use mechanical parts, sensors even before they understand and have the skill to take full advantages of them. But the important thing is that the freshmen now have general conception of mechanical parts and different kinds of sensors. As the result of this, students know what they are going to learn in the following years, and when students are taking courses in the future, they may have more interest and better comprehension.

E. Encourage students to propose their own ideas

The activity in LEGO lab has no detailed instruction for students, and the teacher's responsibility is to bridge the knowledge and students. Students have to work out proposals and solutions by themselves. Without detailed instructions, the minds of students are not constrained at all. They are encouraged to bring out any idea, since the spirit of this activity is no stupid idea [4] [5].

F. Develop the ability of getting information, sharing, thinking and associating

As the development of information technology, the methods for students to get information are more and more [6]. They can obtain information not only from teachers or libraries as before but also from database online, Blogs, E-learning courses, BBS, and so on[7]. The activity in LEGO lab encourages students to get information and find solutions by themselves, and provide opportunities to share their information and solutions with the classmates by presentations.

In addition to working on engineering projects, some students are good at thinking and associating. For example, they know the history of LEGO bricks, the development of LEGO bricks, and why it is so popular in the world to different age people, even have some ideas about the advantages and disadvantages. Excellent students show up though the activities.

III. OUTSIDE OF CLASSROOM DIY ACTIVITY

The purpose of this activity is to manufacture mechanical products by students. This activity requires students spend more time on it. The students are required to propose, design and draw, purchase material and parts from market, manufacture and improve in workshop [8]. Here are two cases.

a). a skateboard bicycle

Figure 4. A skateboard bicycle manufactured by students

This is a bicycle driven by trampling which is different from common bicycle. It was designed and made by two students who majored in mechanics manufacture. They spent spare time doing this at their second year in university, proposing ideas, designing, manufacturing and testing by themselves with some support from supervisors.

b). a chair keeping health with traction system

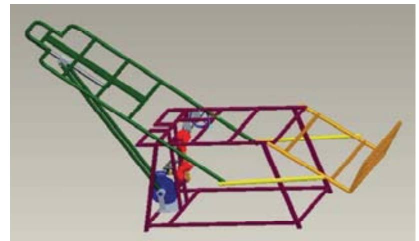


Figure 5. The 3D Assembly drawing of the Chair

Figure 6. Students are Welding the chairs in workshop

Same as the last example, the two students in the picture designed a chair with which people could keep health by dragging neck. Fig. 6 shows two students were welding the chair in the workshop.

CONCLUSION

This paper proposed the activity in LEGO lab based on projects and the outside classroom DIY activities. Those trainings help freshmen understand the whole processes of engineering projects, learn the technology courses they will take with their former experience of LEGO projects and DIY activity. It's vital to freshmen who will get involved in international engineering work in future.

The trainings also increased the passion for engineering of students. A student, Hu Zejun, who joined LEGO project said: *We proposed our own idea to the project. We spent much time, challenged a lot, but at last we know how to find solution by ourselves.* Besides, three students who ever experienced the projects as a group, have proposed an innovation project based on LEGO and gotten support by National University Students Innovation Experiment Program.

To improve the work on freshmen training in the near future, more surveys are necessary for authors to do.

ACKNOWLEDGMENT

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Assessment of the learning competence of Mathematics for freshmen of the Computer Science degree

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Abstract— **Mathematics is an important core of the syllabus of any Computer Science degree. We have studied the relation between the learning competence of Mathematics for first-years at the Universidad Politécnica de Valencia, and their success in the subjects of mathematics in the degree. Its relevance for their success in the whole first academic year is also reported.**

Keywords-component; Bologna Process, Competences, Computer science education, Management education.

I. Introduction

Before 2010, all higher education institutions of the European Higher Education Area (EHEA) would have had adapted their degrees to the Bologna Process. This process has the purposes of promoting lifelong learning, widening access to higher education, and stimulating the mobility across the EHEA [1]. This change does not only consist on a new measurement of the credits of the subjects in terms of the student workload instead of the teaching hours. All contents of the new syllabus should be addressed to the achievement of certain prescribed learning outcomes and competencies associated to the degree [2]. These could be related to general skills or to specific requirements of the professions corresponding to the degree. In both cases, the initial level, if exists, must be known and the desired level should be realistic and achievable. Therefore, an assessment of the initial situation is required.

A project supported by the Spanish Government has been conducted on several Schools and Faculties of Computer Science in Spain [3] in order to state the initial level of competencies of first-years. Reading comprehension, English, and Mathematics were evaluated by analytic rubrics, as a quality label for competences acquisition. The results can be compared with the PISA reports of 2003 and 2006 [4]. Such studies usually cover the period of compulsory education, until 16 years old. However, at least in Spain, nothing can be said about the competence level of the students after the High School period, before enrolling in the University. This is quite surprising since the degrees designed in the frame European Higher Education Area should be designed thinking on learning outcomes and competences that graduate students must have achieved at the end of the degree.

At the Escuela Técnica Superior de Ingeniería Informática (ETSINF) of the Universidad Politécnica de Valencia (UPV) in Spain, we have compared the results on the mathematics competence of our freshmen with their success in mathematical subjects included in the first academic course of the degree. We have also analyzed the level of the students on this competence with their success in all the subjects of the first year. These results can also be compared with other analysis conducted at this institution for first-years [5][6]. Besides, we also try to relate students who drop out of the institution after the first year with their initial level of competence in Mathematics. See also [7][8].

In Spain, children have to take compulsory education until 16 years old. After this period, a Baccalaureate period of two years should be taken in order to apply for a university. We should point out that freshmen of Computer Science have shared Mathematics in the Baccalaureate with students that have finally enrolled in other studies of engineering or science. So that these contents are dedicated to these kind of studies. However, contents of Mathematics in this last year of Baccalaureate are mainly focused on helping the students to pass the university entrance examination (*Selectividad*) that students ought to take in order to access to the University. Therefore, a general improvement of the competence in Mathematics is not the main goal of this course.

II. Computer science degree at the ETSINF

Until 2009/2010 the syllabus of the Computer Science degree at the ETSINF has been made up of 10 semesters (5 years). The number of Spanish credits for the whole syllabus is 375 (1 Spanish credit is equivalent to 10 teaching hours), divided into two stages. The first one takes 6 semesters and the second one takes 4. One academic year comprises two semesters and every semester lasts 14 weeks of teaching, with around 37'5 credits (375 teaching hours), and a period of 3 weeks for examinations.

From 2010/2011 the new degree, according to the new EHEA, will consist on 240 ECTS split in 8 semesters (4 years). Later, there will be a Master degree which will have between 90 and 120 ECTS. Some facts about the adaptation procedure were reported in [9].

Nowadays, Mathematics in the first year of the Computer Science degree at our institution mainly appear in the syllabus of these two subjects:

- **Mathematical Analysis** (Análisis Matemático - AM), 12 credits. It deals with calculus of one and several variables, complex numbers, numerical sequences and series, Fourier series, and ordinary differential equations.
- **Mathematical Structures for Computer Science I** (Estructuras Matemáticas para la Informática I - EMI1), 9 credits. It includes contents of linear algebra (such as systems of linear equations, vector spaces, eigenvalues and eigenvectors), logic (propositional logic and predicate logic), and discrete math (mathematical relations and graph theory).

In the future degree of Computer Science, that will start in the course 2010/2011, the contents of these subjects will be redistributed as follows: **Mathematical Analysis** (6 ECTS), **Discrete Mathematics** (6 ECTS), and **Linear Algebra** (6 ECTS). This distribution will imply a new revision of the syllabus of each subject.

III. The competence level test

In the flavor of the tasks used in the examinations proposed in the frame of the PISA Project, some tests were proposed in order to measure the following competences for the Computer Science freshmen: *Reading comprehension*, *English*, and *Mathematics*. The following Spanish universities were involved in this project: Universidad de Almería, Universidad de Castilla La Mancha, Universitat Politècnica de Catalunya, Universidad Politécnica de Madrid, and Universidad Politécnica de Valencia. A number of 425 students conducted these tests, 107 of them where from the Universidad Politécnica de Valencia.

Depending on the results of the activities related to each competence, rubric procedures were developed in order to classify the level of each student on each competence as *Low*, *Medium*, or *High*. A complete description of this study and its outcomes can be found in [3], see also [11].

All tests and tasks were expected to be done in 2 hours. The Mathematics part was prepared to be done in 20 minutes. Nearly all questions where proposed in a True or False way.

At the ETSINF in the Universidad Politécnica de Valencia, we have deeply analyzed the particular results of our students in the Mathematics competence. For this purpose the questions in the test of the mathematical competence were divided up in two parts: *Calculus* and *Algebra*.

The evaluated Calculus contents are basically included in the subject *Mathematical Analysis*. On the other hand, Algebra is related with *Mathematical Structures for Computer Science I*, since half of its contents are of linear algebra.

The items treated in the Calculus test were graphic representation and elemental properties of functions, derivatives, and primitives. On the other hand, in Algebra we considered algebraic computations, solution of inequalities, lines on the plane, and the solution of systems of linear equations.

IV. Results and discussion

The results in the test of Mathematics' competences, measured using rubrics, have been compared with the marks obtained by this same cohort at the end of the academic year. In Spain the students who fail the final exam after the teaching period can sit for an additional examination during the same course. For these students, we have considered the higher mark obtained in both exams.

In Figure 1 we show the percentages of students obtaining the low, medium, or high level on each of the rubrics (100 % are 107 students from the Universidad Politécnica de Valencia). In both rubrics more than half of the students show a low level of competence (52% in Algebra and 55% in Calculus). These results show us that the level of the questions was quite similar in both cases.

The number of students with a medium level of competence is higher in Algebra than in Calculus (45% and 30% resp.) However, only a 3% of students in Algebra, and a 14% in Calculus got the high level. This could depend on the fact that the text contained some questions on geometry of the plane that are treated in the first year of the baccalaureate period, and they are not considered neither in the university entrance examination nor in the university courses.

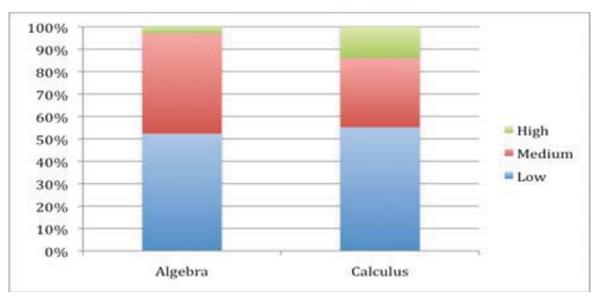

Figure 1. Percentage of students in each level of the rubric.

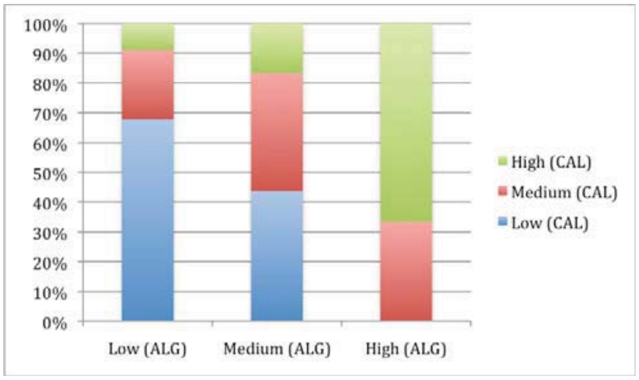

Figure 2. Percentages of students in each level of the Calculus and Algebra rubrics.

Secondly, we have studied the relation between the level on Calculus and Algebra of each student. (See Figure 2). Almost 70% of the students with a low level in Algebra have also a low level in Calculus. The medium level in Algebra corresponds with the medium level in Calculus for the 40% of the students. Finally, almost 70% of the students with a high level in Algebra have also a high level in Calculus. This also Confirms the level of the questions was quite similar in both rubrics.

The levels obtained in each rubric by the students can be compared with the marks that they have obtained in the subjects of EMI 1 (for the rubric of Algebra) and AM (for the rubric of Calculus) at the end of the academic year. This relation can be seen in Figure 3. It is important to recall that in Spain the marks obtained in a subject are from 0 to 10. A mark of 5 is required to pass a subject.

We should point out that in order to compute this average, students who did not sit for examination but did the test were also considered. A mark of 0 was assigned to these students. This fact makes the average of the marks lower than the corresponding average of the students who sit for examination in these subjects. However, we consider that exclude the results of these students will distort our study.

In Figure 3, we have represented, for each level, the mean plus/minus the standard deviation of the marks. For EMI 1 the standard deviation of the marks corresponding to each level of the rubric was (2.7 for low, 2.92 for medium, and 0.45 for high).

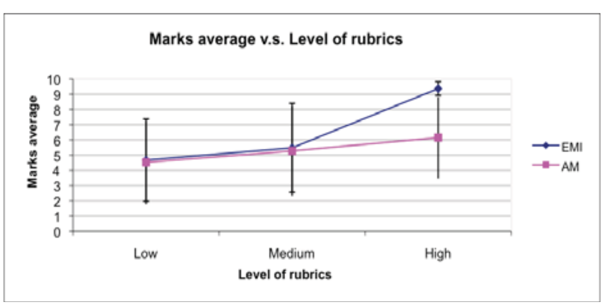

Figure 3. Marks average on EMI 1 and AM vs. level on each rubric.

In AM the corresponding standard deviations were quite similar for students with a low or medium level (2.74 for low, 2.95 for medium), and much more bigger for students with a high level (2.67).

The fact that some students who did not sit for the examination were considered makes that the deviations were quite significant for the low and medium levels, where these students were supposed to be classified.

We also see that the small number of students having a high level in the Algebra rubric show a mark very high in EMI 1 (about 9.5). This fact is different from the rest of groups where a linear relation has been established between the level on the rubric and the average of the marks in the corresponding subjects.

At this point one can wonder if the differences observed in the results of rubrics and the corresponding marks on AM and EMI 1 would imply, really, different populations. In order to measure if the means of the marks obtained in each of the cases correspond to different groups, we have used the t-statistic test, by computing the probability that the different means of the marks were significative. In the next table we show the probability (percentage) that the differences in marks between different pairs of groups are significative. The study has been carried out between the different groups of Algebra, and on the other hand, the different groups of Calculus:

TABLE I. PROBABILITY (EQUAL OR HIGHER) THAT THE DIFFERENT MEANS OF THE OBTAINED MARKS ARE SIGNIFICATIVE. GROUPS COMPARED ARE H (HIGH) VS. M (MEDIUM) LEVEL, H VS. L (LOW), AND M VS. L, BOTH IN ALGEBRA AND CALCULUS.

	Algebra	**Calculus**
High-Medium	95%	60%
High-Low	99%	95%
Medium-Low	80%	70%

These data shows that the groups established by each rubric have in fact different means with a probability, at least, of 60%. In the case of the comparison between the high and low level, the probability is higher than 90% (95% for the Algebra rubric).

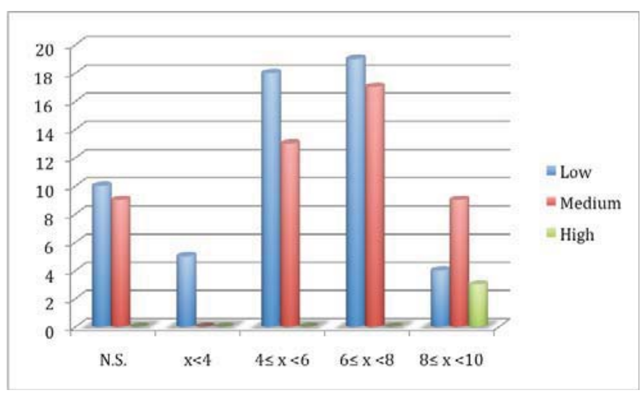

Figure 4. Distribution of the marks in EMI 1 depending on the level of competence in Algebra.

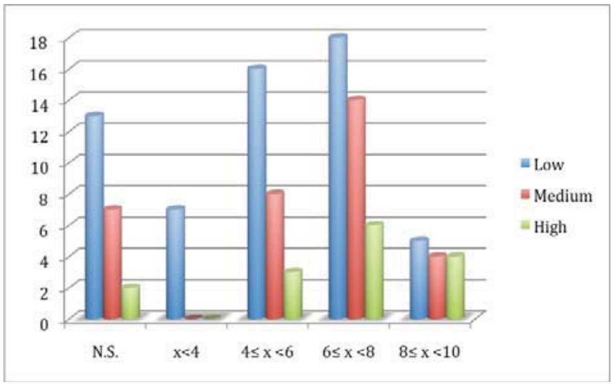

Figure 5. Distribution of the marks in AM depending on the level of competence in Calculus.

In addition, we have considered the relation between the level obtained on the rubrics and the distribution of marks in the subjects of EMI 1 and AM. These distributions can be seen in Figures 4 and 5. We have considered the following groups NS (who did not sit for examination), less than 4, greater or equal than 4 and smaller than 6, greater or equal than 6 and smaller than 8, and finally, greater or equal than 8.

In both rubrics it can be found similar patterns for the distribution of marks:

- In all groups of each rubric, most of marks in the corresponding subject are between 4 and 8; for the low level, the highest weight is between 4 and 6, and between 6 and 8 for the medium level.
- For the high and medium levels, the weight of the marks greater than 8 increases. In the case of Algebra it covers the 100%.
- All students with marks smaller than 4 in AM or EMI 1 got a low level in its corresponding rubric.
- The number of students who did not sit for examination is similar for the students with a low or medium level in the corresponding rubric.
- Only students with a low level in the rubric get a mark smaller than 4 in the subject.

The number of credits passed by the students is strongly related with the marks obtained by them in the subjects of EMI1 and AM, as Figure 6 shows: There is a linear increase in the number of passed credits in the first academic year as the results in the rubric are improved.

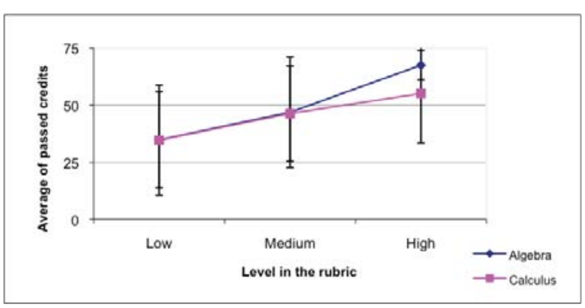

Figure 6. Approved credits by pupil vs. the level of the rubric for each group.

Finally, we have to point out that all students that did the test were also enrolled in the degree the next year. Nearly none of them has dropped out of the degree.

This was not the expected situation observed some years ago in [8]. This situation has probably happened because the test was taken during the second semester of the first academic year.

The interesting point is that we have noticed that all students who will not go on with the degree have already taken their decision in this moment of the academic course. On the other hand, the economic crisis is probably forcing the students to keep on studying at the university, as they cannot find easily a job.

V. Conclusions

To sum up, in both cases, Calculus and Algebra, the classification of the students in rubrics have similar results. This fact is an evidence of the coherent design of both, the tests and the rubrics. Therefore we can affirm that the level of competence in Mathematics acquired during High School of the students of the Computer Science degree, is strongly related with the success in all Mathematics subjects of this degree.

Also, students with lower level of competence can even pass the subjects of Mathematics. This can happen because in some cases they know the solution procedure of some problems but they do not really understand the meaning or intuition of the mathematical topics.

In any case, students with a low level of competence in Mathematics have smaller chance to succeed in the mathematical subjects of the degree. Furthermore, the level in Mathematics is strongly related with the success in the rest of the subjects of the first academic year.

The PISA reports [4] set the competence in Mathematics of the Spanish students a little below than the average of the OCDE countries. This situation is not getting better during the sequent years. The High School period has only two courses, and in the second one the students should be prepared to pass the University entrance examination. All questions and

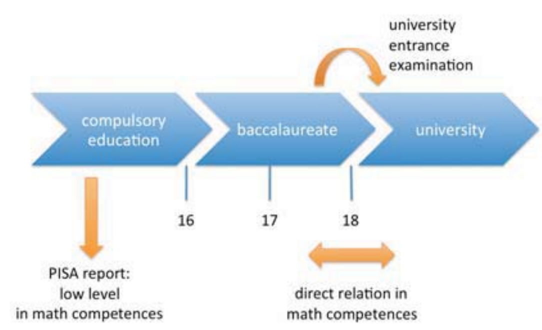

Figure 7. Diagram of the situation of the mathematical competences in secondary education and university.

contents of this examination are quite defined, so during this second course the outcomes expected are focused on solving the problems that will appear in this exam. The develope of the mathematical intuition plays second fiddle.

Since it is clear that the good level in the mathematical competences improves the success in the Computer Science degree, then the level on it should be improved. Great efforts must be done in compulsory education as the PISA reports suggest. Another option is to propose an enlargement of the Baccalaureate, probably separating the students in the last year of compulsory education depending on their interests, or adding one more year to the Baccalaureate.

Until the changes in these periods happen, the Faculties and Schools of Computer Science should try to improve the mathematical competences of their students. This can be done offering groups, during the first academic course, to support the students having great deficiencies in basic notions of mathematics. Besides, in the programs of mathematics subjects in the new Computer Science degrees, more attention must be paid to mathematical notions and concepts, despite that the number of ECTS has probably been reduced.

Acknowledgment

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Analysis of the results of four years of research and application of a student-centered system based on the ECTS to first-year students in order to improve their performance in the subject AC-I

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***Abstract*—In this paper, the results of four years of a research aimed at carrying out a comparative analysis between the application of the European Credit Transfer and Accumulation System (ECTS) and the traditional teaching and learning system (TTLS) to first-year students, in order to improve their performance in the subject Analysis of Circuits I (AC-I) are presented. The ECTS is a student-centered system based on the student workload required to achieve the objectives of a program, and the outcomes of its application have been quite positive. In order to conduct the statistical analysis of the data collected in the educational experiment and make the right decisions, at the beginning of the experiment, during the first years, both treatment and control groups were formed and several tests of hypothesis were conducted in the groups that participated in the educational experiment. Neither all the students who took the above-mentioned subjects nor all the professors who taught them participated in the experiment. However, during the last year of the experiment all the students and almost all professors participated in the experiment. Since the beginning of the experiment, satisfactory partial results have been gradually achieved, and when we managed to involve all the students and almost all professors in the last year of the experiment, the overall results where not only satisfactory but also significantly better than the ones achieved in the previous years. The students satisfaction and confidence have increased gradually, and, in general, the students under the ECTS passed more exams and with better Grades than the students under the TTLS. Also, the teaching-learning methodology strategies, tutor sessions, assessment methods, use of the virtual learning environment (VLE), student teamwork, and collaborative work among professors performed better under the ECTS than under the TTLS.**

***Index Terms*—student-centered learning system, first-year students, statistical analysis**

I. Introduction

In this paper the results of four years of research and application of a student-centered learning system (SCLS) to improve the performance of first-year students (FYS) in the subject AC-I are presented. The above-mentioned SCLS is based on the application of the ECTS [1] to the EUIT de Telecomunicación (EUITT) at the Universidad Politécnica de Madrid (UPM), and was born five years ago as a result of the adaptation of the first-year course of the EUITT-UPM to the European Higher Education Area [2].

Since the academic year 2005-2006 in the EUITT-UPM the higher education system has experienced a positive change from the traditional teaching and learning system (TTLS), which has failed to motivate students for further learning and does not take into consideration their needs and perceptions, to novel systems based on the student workload required to achieve the objectives of programs.

While in the TTLS credits are given only for student workload in class, without taking into consideration the independent and private study, and the preparation of projects and examinations either, in the SCLS mentioned in this paper credits can only be obtained after successful completion of the work required and appropriate assessment of the learning outcomes achieved.

The learning outcomes are sets of competences, expressing what the student will know, understand or be able to do after completion of a process of learning [1].

In the EUITT-UPM, both the TTLS and the SCLS consisted of 15 teaching weeks, and the subject AC-I had allocated 7.5 non-ECTS credits for the TTLS and 7.14 ECTS credits for the SCLS [3].

1 non-ECTS credit stands for 10 working hours of the students in lectures, seminars and laboratory sessions, without taking into consideration the student workload after classes, the independent and private study, and examinations.

1 ECTS credit stands for around 25 to 30 working hours and, as mentioned in previous sections, credits in ECTS can only be obtained after successful completion of the work required and appropriate assessment of the learning outcomes achieved.

Thus, due to the fact that the current emphasis is on understanding and measuring students' learning, rather than teaching [4], the content-centered approach [5] is soon-to-be obsolete and the current higher education system is moving on to the student-centered approach [5]. In the latter, developing the cognitive abilities of the students is of paramount importance rather than teaching, and it also applies collaborative and cooperative learning methodologies efficiently [6], [7], [8].

The subject AC-I is a fundamental one and it is taught in the first semester of the first-year course in the EUITT-UPM. Also, the students that take this subject can be either new first-year students or students who are taking the subject again. Several educational experiments have been conducted in order to improve the performance of the students in AC-I, and their results have shown that when the academic results of one year are compared with the ones of another year the differences between both are not always significant. Therefore, professors have to keep themselves improving the teaching and learning system continuously.

In this paper the problem of analysis of the results of the educational experiment is formulated as a statistical analysis problem and some decisions about the efficiency of the proposed SCLS on the basis of sample information are made.

II. General description of the educational experiment that have been conducted in the last four years

A. First two stages of the experiment: All first-year subjects

The beginning of the educational experiment dates back to the academic year 2005-2006. In that stage of the research the coordination among the 14 professors that decided to participate voluntarily in it was the key issue. There were professors from different departments and from all the subjects that are taught in the first academic year of the EUITT-UPM [3], AC-I was one of the subjects under study.

Generally speaking, the research group had several regular meetings during the whole academic year and, after each meeting of the research group, several important decisions regarding the curriculum development and the application of the ECTS to the EUITT-UPM were made. Such decisions were focussed on the following issues:

1) Determining the student workload and its translation to ECTS.
2) Developing new educational methods that guarantee the perfect harmony among all the subjects.
3) Promoting tutor session.
4) Applying the same evaluation methods in all the subjects.
5) Setting the standards of using the Virtual Learning Environment (VLE).
6) Strengthening the cooperation among all the subjects taught during the academic year.

Also, during the academic year 2005-2006 32 new first-year students (FYS) were chosen to participate in this educational experience. These students were chosen at random from a group of 150 new FYS that wanted to participate voluntarily in the educational experiment. Those students had both a lecture room designed to facilitate teamwork (with Wi-Fi technology, laptop computers, a slide projector and adjustable desks aimed at making the students feel comfortable in the classroom), and a laboratory room consisting of 16 student workbenches equipped with the conventional laboratory instrumentation that can be found in an electronic engineer's workbench [9].

At that time, it was decided to design each semester taking into consideration that the student workload is 800 hours and that during the examination weeks the students devote 20 hours to study each particular subject to successfully pass the final exams. The marking scheme for each subject was constructed as follows: 70 % exam paper and 30 % continuous assessment, including participation in classes and activities developed in the VLE; and for the VLE the software system used Moodle.

Furthermore, the VLE was used to provide follow-up materials online, continuous assessment tasks for their (online) discussion, homework assignments, and online activities or exercises. Also, it was used to make available the material from the professors and the scheduling of each unit of work, to participate in forums assigned by the professors, and to provide forum questions and e-mentoring or e-tutoring.

During the second stage of the educational experiment, the academic year 2006-2007, the working methodology was the same as the one of the first year, the number of new FYS that participated in the experiment was 90 and the number of professors was 17. In addition, the new FYS that participated in the educational experiment were not asked whether they wanted to participate voluntarily in the experiment. But they were all informed about the project when they came to the school to enrol in the academic year 2006-2007, and at that time the professors let the students know that some of them were going to be chosen at random to participate in the project.

Generally speaking, during the first two stages of the educational experiment, which focussed on all the first-year subjects, the overall opinion of both students and professors was quite positive. The two things that they both valued the most were the continuous assessment and the use of the VLE as a support to both the developing of student learning skills and the collaboration and cooperation among students.

On the other hand, as at university professors have also to do research on other fields such as Telecommunication Engineering, Electronics, Physics, Mathematics and so on, the general opinion of them was that the pass from the traditional teaching and learning methodology to the new one had caused an increased in their workload, at least in the first two stages of the educational research project. Also, in spite of the fact that most of the students who participated in the project were in favor of the new methodology, some of them thought that the workload was higher [10], [11].

Therefore, in order to make the system more efficient and to find one that works best for both professors and students, some decisions were made during the third stage of the experiment, the academic year 2007-2008. For instance, that academic year faculty and student mentors were introduced, and all the lecture rooms of the school for first-year students were designed to facilitate teamwork among students and to make them feel comfortable in classes.

Moreover, in that academic year there were two kind of groups of students, one consisting of new FYS and the other consisting of students who were taking the subjects again. Also, in the academic year 2007-2008 the marking scheme depended more on continuous assessment tasks (i.e., partial exams, tests, projects, homework assignments, and so on) than on the final exam paper. In fact, in AC-I outstanding students did not have to do the final exam paper, they passed the subject if their performance in the continuous assessment tasks was very good.

In order to round-up the first two stages, it can be said that there were weaknesses such as the high student and professor workload, and threats such as the lack of communication among the professors that participated in the project and the ones that did not participate in it, some professors were not 100% willing to change from the TTLS to the SCLS based on the ECTS, some professors did not consider research in Engineering Education as scientific research, and in order to improve communication, teamwork and lateral thinking, the amount of interdisciplinary lessons had to be increased.

However, on the other hand, there were also strengths such as the overall improvement of the student performance in all the subjects, the blended approach to teaching, face-to-face and e-learning, the use of interactive methods to break the monotony, the use of the VLE, the good coordination and cooperation among all the professors subjects that are participating in the project, and so on; and there were many opportunities as well, in its first two stages the educational experiment allowed us to enjoy the benefits of the new teaching and learning methodology, and to be prepared for collaboration and cooperation in excellence in engineering education with other member states of the European Community.

Taking into consideration both the positive aspects and the things that the research group had to improve from the first two years of the educational experience, it was decided to continue the research focusing only on each specific subject, instead of focusing on all the first-year subjects at the same time.

To that end, the resources were optimized and the research group tried to involve more professors of each specific subject in the experiment, which in contrast to the first two years of the experiment in the case of AC-I it has been a success since the academic year 2007-2008. Currently, all the professors who teach that subject have gotten involved in the experiment.

The next third and fourth stages of the educational experiment that will be described next (i.e., academic years 2007-2008 and 2008-2009), will be devoted specifically to describe the part of the experiment focused only on the subject AC-I.

B. Last two stages of the experiment: AC-I

During the third stage of the educational experiment, the academic year 2007-2008, the working methodology was the same as the one of the first two years and, as mentioned above, some decisions were made to make the system more efficient and better adapted to the needs of both students and professors. In this stage of the experiment 222 students who had to take the subject AC-I were chosen to participate in the experiment. Those students were chosen at random from the group of 444 students that were enrolled in AC-I in the first semester of the academic year 2007-2008 [12].

Also, those 222 students were divided into 4 groups of students with the following characteristics:

1) Group A: 50 new FYS. These students studied under the TTLS.
2) Group B: 47 new FYS. These students studied under the SCLS.
3) Group C: 64 students who were taking the subject again. These students studied under the SCLS.
4) Group D: 61 students who were taking the subject again. These students studied under the TTLS.

In addition, the number of professors of AC-I who participated voluntarily in the experiment was 4. Two of them had good experience with the application of the student-centered approach to improve the performance of students, and the other two professors had good experience with the application of the TTLS.

Furthermore, for the TTLS the marking scheme for AC-I was constructed as follows: 75% the final exam paper, which is done by the students in one specific day during the examination weeks, after having finished the 15 teaching weeks of the semester, and 25% the laboratory exam in the last week of the semester.

Taking into consideration the results of the two previous academic years, in the third stage of the experiment for the SCLS it was decided to construct the marking scheme based on continuous assessment tasks as follows: two exam papers, 30% the first exam paper (in the middle of the semester) and 37.5% the second exam paper (in the last week of the semester); 7.5% ten 30-minute knowledge tests given to the students during all the semester (two 10-questions knowledge tests given at the end of each one of the five units of work of AC-I), this activity was carried out using the VLE and the tests were made by using the platform Moodle; and 25% continuous assessment activities in the laboratory including a final laboratory exam in the last week of the semester.

Also, the professors who participated in the educational experiment prepared the knowledge tests in Moodle in such a way that none of the tests that the 222 students had to do had the same 10 questions. The questions were chosen at random by Moodle.

The 10 knowledge tests (i.e., 2 tests for each unit of work) that were given during all the semester were mandatory for the students of the Groups B and C. However, these tests were optional for the students of Groups A and D.

An example of the full version of one of the above-mentioned 10-questions knowledge tests can be found in the Appendix of [12].

Finally, during the academic year 2008-2009, the last stage of the experiment, all the FYS (i.e., new FYS and students who were taking the subject again) participated in the experiment and the number of professors who taught the subject AC-I that participated in the experiment was 7.

Moreover, from that academic year on the marking scheme was the same for all the students: 3.75% ten 30-minute knowledge tests given to the students during all the semester, those tests had the same characteristics as the ones of the academic year 2007-2008; 15% the partial exam paper (there was only one) in the middle of the semester; 56.25% the final exam paper; and 25% the laboratory exam in the last week of the semester.

As will be shown in the next section, the academic results of that year were the best, both professors and students were very happy with them and in many aspects all the effort of many years of the educational experiment started to pay back.

III. Statistical analysis of the general academic results of the students during the experiment

In order to conduct a comparative analysis between the general academic results of all the FYS right before the beginning of the experiment and the ones during the last four years of it, a comparison of the final Grades in the subject AC-I among the years 2004, 2005, 2006, 2007, 2008 and 2009 was carried out in order to say, on the basis of the evidence obtained, whether the observed differences were significant and either accept or reject the hypothesis that the students under the SCLS based on the ECTS performed better than under the TTLS.

At this point, it is important to point out that the years 2004 and 2005 are important because they were the last two years in which there was no research in engineering education in the above subject. From those years on the research started with a small group of FYS students and only 2 professors of AC-I, and at present (in the academic year 2009-2010) all the FYS and all the professors who teach AC-I are involved in it, which has been a significant step forward in the educational experiment.

The first step of this section was to conduct an exploratory examination of the data. To that end, the R system for statistical computing was used [13], the data set was loaded and the variables (Grades2004, Grades2005, Grades2006, Grades2007, Grades2008, Grades2009) accessed.

Figure 1 shows the Box-plot of the data and Table I shows some summary statistics.

Figure 2 shows the histogram and density estimate of the Grades of the years (2004, 2005, 2006, 2007, 2008 and 2009) [14]. From that figure it can be seen that the distributions are strongly skewed.

The model

$$y_{ij} = \mu_i + e_{ij} \quad i = 1, \ldots, 6 \quad j = 1, \ldots, n_i \qquad (1)$$

is considered. Here, $\mu_i, \quad i = 1, \ldots, 6$, are the mean value of the final Grades of the students, e_{ij} are random errors that follow a normal distribution with zero mean value and standard deviation σ, and $n_i,\ i = 1, \ldots, 6$, is the length of the each variable.

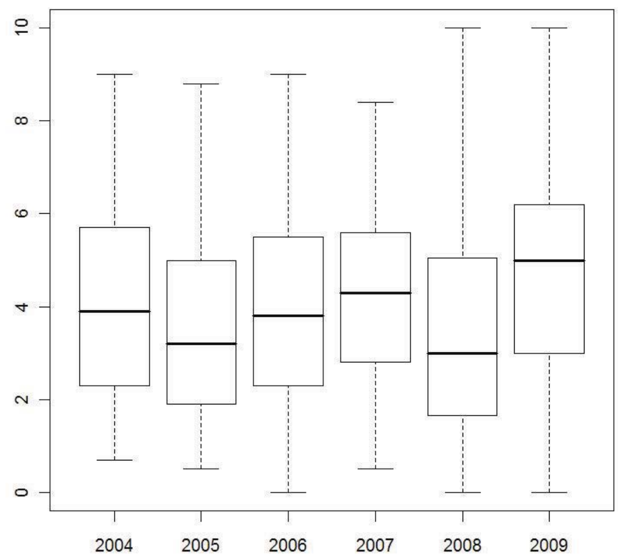

Fig. 1. Boxplot of data

Next, an F test [15] was carried out to see if the means of the Grades were equals.

The hypothesis is

$$H_0 : \mu_1 = \mu_2 = \ldots = \mu_6$$

against

$$H_1 : \mu_i \neq \mu_j \quad \text{for at least one pair } i, j,$$
$$\forall \quad i, j \in \{1, \ldots, 6\}$$

at level 0.05.

Then, the residuals were used to check the adequacy of the fitted model using a normal Q-Q Plot (see Figure 3) and a normality test statistic (see Table II).

Therefore, the model (1) is considered when random errors do not follow a normal distribution.

Now, the problem may be solved by a rank test such as Kruskal-Wallis [16], [17]. In that sense, Table III was obtained.

Then as shown by the p-value of the KrusKal-Wallis test, H_0 had to be rejected. Therefore, the statistical analysis continued with the study of the academic years in which it can be said that there were significant differences. In short, the experimental groups that led to the rejection of the null hypothesis were investigated. Such an investigation was carried out by using a post-hoc comparison test [18].

To that end, a pairwise permutation test we applied to all possible pairs of groups and as a result, for the data under analysis, it was found that there were significant differences among the final Grades of the students. This information is shown in Table IV.

TABLE I
SUMMARY STATISTICS

	Grades2004	Grades2005	Grades2006	Grades2007	Grades2008	Grades2009
Min	0.700	0.500	0.000	0.500	0.000	0.000
1st.Qu	2.300	1.900	2.300	2.800	1.675	3.025
Median	3.900	3.200	3.800	4.300	3.000	5.000
Mean	4.112	3.437	3.991	4.257	3.517	4.685
3rd.Qu	5.700	5.000	5.500	5.575	5.025	6.200
Max	9.000	8.800	9.000	8.400	10.000	10.000
sd	1.996	1.788	2.028	1.892	2.204	2.184

TABLE II
SHAPIRO-WILK NORMALITY TEST

Shapiro-Wilk normality test
data: residuals
W = 0.9773, p-value $<$ 2.2e-16

TABLE III
KRUSKAL-WALLIS TEST

Kruskal-Wallis rank sum test
data: Teleco and year
Kruskal-Wallis chi-squared = 77.6375, df = 5
p-value = 2.617e-15

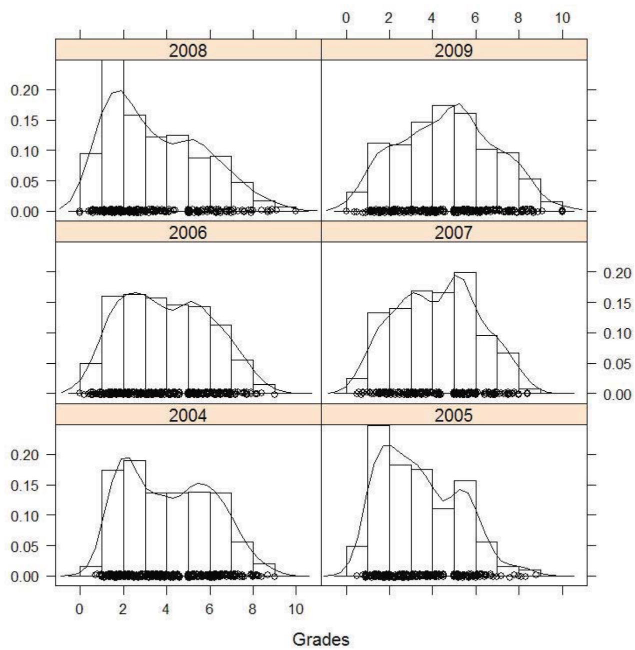

Fig. 2. Histogram and density estimate of variables

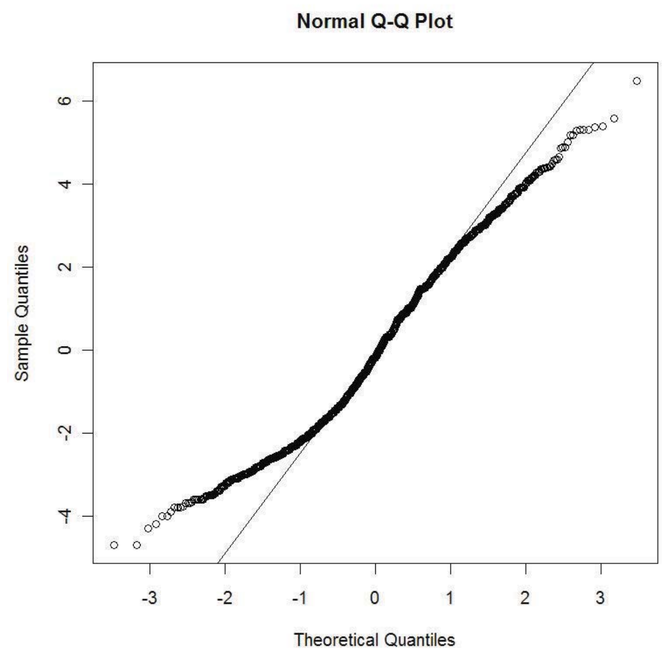

Fig. 3. Normal Q-Q plot

In Table IV, the partial p-values are highlighted with the usual R convention [13]:

Signif. codes: 0 `***´ 0.001 `**´ 0.01 `*´ 0.05 `.´ 0.1 ` ´ 1

Also, in Table IV `***´ stands for that the observed differences between the specific years under analysis were highly significant, `**´ stands for that the observed differences between the specific years under analysis were very significant, `*´ stands for that the observed differences between the specific years under analysis were significant, and ` ´ stands for that, on the basis of the evidence obtained, the observed differences between the specific years under analysis were not significant.

Table IV shows that the best year was the year 2009, the two second best years were 2004, 2006 and 2007, and the worst years were the years 2005 and 2008.

The general results of the year 2005 motivated the application of the SCLS based on the ECTS to improve the performance of the students and the general results of the year 2008 motivated a change of philosophy.

TABLE IV
PAIRWISE COMPARISON TABLE

	Diff	Partial p.value	
2004-2005	0.67446635	0.000999001	***
2004-2006	0.12052494	0.419580420	
2004-2007	-0.14480756	0.351648352	
2004-2008	0.59491212	0.001998002	**
2004-2009	-0.57359972	0.000999001	***
2005-2006	-0.55394141	0.000999001	***
2005-2007	-0.81927391	0.000999001	***
2005-2008	-0.07955423	0.624375624	
2005-2009	-1.24806606	0.000999001	***
2006-2007	-0.26533250	0.128871129	
2006-2008	0.47438718	0.001998002	**
2006-2009	-0.69412466	0.000999001	***
2007-2008	0.73971968	0.000999001	***
2007-2009	-0.42879216	0.015984016	*
2008-2009	-1.16851183	0.000999001	***

Such a change was necessary because in spite of the fact that the new FYS that were taught under the SCLS in the academic year 2007-2008 had significatively better performance in AC-I than the ones that were taught under the TTLS [12], and that the performance of the students who were taking the subject again that were taught under the SCLS was slightly better the ones that were taking the subject again and were taught under the TTLS, not all the students and professors were involved in the educational experience.

Therefore, taking into consideration both the positive aspects and the things that had to be improved from the academic year 2007-2008 [12], in the academic year 2008-2009 the research group focused its efforts on improving the collaborative and cooperative work among professors and among students as well, on improving the common teaching and learning methodologies, and on trying to involve everyone who was related with the subject AC-I in the experiment. Section II-B was devoted to give a general explanation of what the research group has done since the academic years 2007-2008 and 2008-2009 in order to improve the performance of the students in AC-I.

IV. CONCLUSION

The statistical analysis presented this paper has shown that the application of the SCLS based on the ECTS to improve the performance of FYS in the subject AC-I has yielded satisfactory results. In spite of the fact that there were years in which there was not a significant improvement in the performance of the students and others in which the improvement was slightly better than others, there were years in which there were highly significant differences. The best year was 2009 and the worst were 2005 and 2008.

The results of the year 2005 motivated the application of the SCLS and the results of the year 2008 motivated a significant improvement in the way the SCLS had been applied. Such improvements allowed the professors of the subject to obtain in the year 2009 the best performance of the students in AC-I in the last 10 years.

The overall satisfaction of the students and the professors that participated in this educational experiment was quite positive. Their level of satisfaction was high and their reactions to the improvements in the SCLS were quite positives.

With the SCLS based on the ECTS students have to work harder than with the TTLS but they learn more, pass the subjects with better marks and develop skills that will help them to become good professionals.

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A Concept Map Approach for Introduction to Computer Engineering Course Curriculum

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***Abstract*— As in any discipline, in Computer Engineering, students start learning the basic concepts of the discipline in their first year through an Introduction to Computer Engineering course. The topics toughed in this course can be grouped into two. The first group includes simple concepts like binary numbering system, hard disk, memory, and I/O devices. In the second group, an introduction to the courses that they will take in the next semesters of the program which includes programming, networking, software engineering, artificial intelligence and database systems. The main objective of this course is to give an introduction about the general concepts of the field to the first year Computer Engineering students and prepare them to understand the connections between them for their future studies.**

However, students and instructors face with many problems in this course. First, because of the diversity of the concepts given in the course, it is very difficult for the students to see the big picture of the Computer Engineering domain. Similarly, it is difficult for the instructors to prepare the course content in an integrated manner at the students' level. Additionally, the perception of the theory and practice behind the hardware and software topics and their connections is not an easy task for the beginners. Moreover, the topics are mostly abstract topics, which do not allow application of any laboratory sessions. Students usually find this course difficult to understand, which decreases their motivation about the department and success of the course.

This study is established to propose a concept map approach to better visualize and discover all the connections between the concepts of Computer Engineering field which can be used in the curriculum of the programs and introductory courses of the field addressing the above problems. The proposed concept map helps to visualize the general picture of the field.

***Index Terms*—curriculum development, concept maps, computer engineering**

I. INTRODUCTION

Because of the very nature of the rapidly changing technologies, several problems have been faced with for establishing the computer engineering curriculum. The curriculum of such programs need to provide theory and practice on basic concepts of the field such as hardware, digital logics, computer organization, and architecture, programming languages, operating systems, computer networks, database systems and data structures. As declared by Nisan [1], the overall interactions among hardware, software, compilers and operating systems used to be simple and transparent enough for understanding computer systems. However the modern computer technologies have become increasingly more complex which makes it very difficult to understand the whole system of the computers [1]. Accordingly, this complex structure puts pressure on the designers of introductory courses [2] and curriculum developers of such programs. Main problems addressed in the literature can be summarized as below:

- Until their junior or senior year, potential majors do not find what the major is really about [3].
- Many students often assume that computer science education is not about ideas and creativity, but is about learning technology and syntax of programming languages [4].
- Non-majors believe that computer science is only about programming [3].
- Introductory computer science courses do not introduce students how computer scientists address important problems of the field [3].
- The curriculum of these programs provide the theory and practice on main concepts of the field however it is hard to build connections among different components of the computer systems.

Accordingly, two main problems can be addressed from these views. Firstly, for the introductory courses, it is hard to organize the course for better providing the relationships among concepts of computer engineering programs which would make students lose their interest and motivation at their first year. Secondly, while developing a curriculum of such programs it is hard to show the relationships among courses and additionally build a balance on different dimensions of the programs. Since the field of the computer engineering getting larger by including many hardware and software issues as well as the human factors, the curriculum of such programs may vary on the ratio of distribution of different tracks of the field. In that case, defining different dimensions of the field becomes a necessity. For example, for balancing the programming courses and hardware courses ratio based on the general vision of the whole program sometimes need to be considered. This helps the students as well as the program developers to see how well the program fits the expectations.

On the other hand, concept maps are the tools used to build relationships among concepts. These tools have been used in educational environments to better connect the relationships among theory and practice as well as among other concepts covered in a course. These tools also help the learners build relationships between previous knowledge and newly introduced concepts, encouraging meaningful learning rather than rote learning (memorizing concepts, no relationship to previous learning) [5].

In our university, an introductory course has been offered for the computer engineering students. The problems discussed above are all faced in this course and the computer engineering program as well. Accordingly, in this study to address these problems a concept map is developed which builds relationships among the tracks in the field of computer engineering. Main objective of this concept map was three folded:

- to build connections among the concepts given in the introductory course of the field,
- to provide a general idea about the general structure of the program,
- to build the connections among the courses in the computer engineering curriculum.

This study describes the introductory course and the curriculum of the program. Then, it provides the proposed concept map for describing general tracks and dimensions of the field. For the development of the concept map, a new approach called "Goal-Question-Concept" is applied. Lastly, it shows the relationships among the introductory course as well as the curriculum of the program. We believe that, this concept map can be used as a base to build connections about different subjects given in the introductory course and can be introduced in each course to address the relationship between the content of the course and the whole program. This would help the educators to better show the connections between theory and practice issued introduced in a specific course and their connections with the field and prepare course content according to the concept map interactions. Also it would help the students to better build the connections among different concepts of the whole computer engineering program.

II. Course Description

The course "Introduction to Computer Engineering", is taught as the first course for Computer Engineering, and Software Engineering majors. Students with diverse backgrounds and different expectations are introduced to the basic concepts of the domain. Some of them know some coding and think computer engineering is just coding, and some do not have any idea about the domain and feel very insecure and scared. The class is not homogeneous which makes the things more difficult for the instructor.

The main objective is to teach general computer engineering and engineering concepts together with programming fundamentals. At the completion of this course, students are expected to:

- Discuss computer data representation and basic computer operations
- Appreciate the use of machine language
- Describe basic components of a computer system
- Acquire basics of problem solving and programming
- Have a general knowledge on different aspects of computer engineering

Course is planned as 14 week period, 2 hours of lectures in a class environment and 2 hours of lab sessions each week. The basic concepts of the Computer Engineering are taught in the lectures, while basic computer literacy practices like word processing, spreadsheet usage are taught at the lab sessions. The lectures include broad coverage; simple concepts like binary numbering system, hard disk, memory, and I/O devices and more advanced ones like programming languages, networking, software engineering, artificial intelligence and database systems. As a text book, we follow J.Glenn Brookshear's Computer Science: An overview book. the content of the book [8] is as follows:

- Chapter 0 Introduction
- Chapter 1 Data Storage
- Chapter 2 Data Manipulation
- Chapter 3 Operating Systems
- Chapter 4 Networking and the Internet
- Chapter 5 Algorithms
- Chapter 6 Programming Languages
- Chapter 7 Software Engineering
- Chapter 8 Data Abstractions
- Chapter 9 Database Systems
- Chapter 10 Computer Graphics
- Chapter 11 Artificial Intelligence
- Chapter 12 Theory of Computation

We start introducing algorithms, history of computation, then continue with data storage concepts which include storage of bits, main memory, mass storage, representing different type of information in computer systems, numbering systems, Boolean algebra, gates, flip-flops, machine architecture, machine language and program execution. Then concepts of operating systems, networking & Internet, software engineering, programming languages, database systems, artificial intelligence and Algorithms and C language Programming Basics are taught.

As these topics are covered in 14 weeks, each related chapter from the book is referred. However, the connection between them is not emphasized anywhere in the course which creates an unclear, complex picture in the students minds. They just perceive each topic as independent from each other and can not elicit the correlation of them. They generally come up with the argument that the course is boring, has no use, difficult to understand. Consequently, since they cannot realize the importance of these concepts, they do not appreciate computer engineering area, get demotivated at their first semester in the department.

III. COMPUTER ENGINEERING PROGRAM

The computer Engineering program is a 4 years program and containing hardware and software issues. The courses offered by the department are described in the Appendix. The first digit of the course number indicates the year it is offered in the curriculum. TE courses are technical electives (students should choose 5 of them according to the their interests). For choosing the TE courses students face problems because they cannot relate the courses and the field applications. Therefore, they confuse to decide which course is more beneficial for their professional life. Remaining courses are the core courses that are mandatory. Additional to those courses students should take general purpose courses like math, physics, chemistry, and English.

Each course listed in the Appendix, provides subjects related to its own domain and no connection is built between the course and the other courses of the curriculum. The only course students integrate the knowledge they obtained during their 4 year study is the senior project courses, Compe 491-492, which are taught at the fourth year. Until that time, they do not have clear picture of which part of the real life problems of the area each course addresses and how they are linked together. They complain about how they will use the knowledge they gain in these courses some of which are pure theoretical courses. Consequently, they learn the subject without awareness and they generally conclude that other than the programming courses, most of courses are unnecessary for them, and they are wasting time with those subjects.

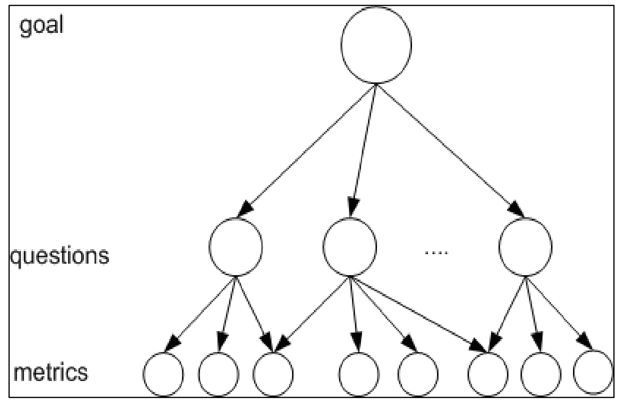
IV. PROPOSED CONCEPT MAP

We propose to use a concept map to built connections between the concepts taught in Introduction to Computer Engineering course. While preparing the concept map, we applied a new paradigm called "Goal- Question-Concept" inspired from a well-known GQM (Goal-Question-Metric) method of software engineering field. GQM was introduced to identify problems in a software process or product and define improvement goals for them for software process improvement. It builds a connection between software goals; questions to be answered for each goal and metrics as answers to the questions [6] as illustrated in Figure 1.

The ultimate goal of a computer system is to serve users by supporting them to improve their performance in their daily lives.

In order to reach this goal we have to answer the following questions:

1. What type of requirements do the users have?
2. What type of system parts needed to be developed based on these requirements?
3. What are the relations between these system parts
4. How these parts should be integrated to create the required system?



5. How this system will serve users to support their tasks?

Figure 1. GQM Technique [7]

The next step is to identify and categorize the concepts related to each question, which should be placed in the concept map. Accordingly, we came up with the top level concepts that should be considered as answers to these questions. These top level concepts can be decomposed to lower levels to reveal the partially detailed concept maps.

For the top level concept map, for answering the first question, we categorized the user requirements as shown in Figure 2.

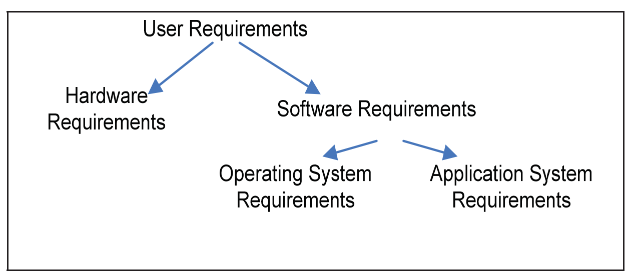


Figure 2. Requirements decomposition

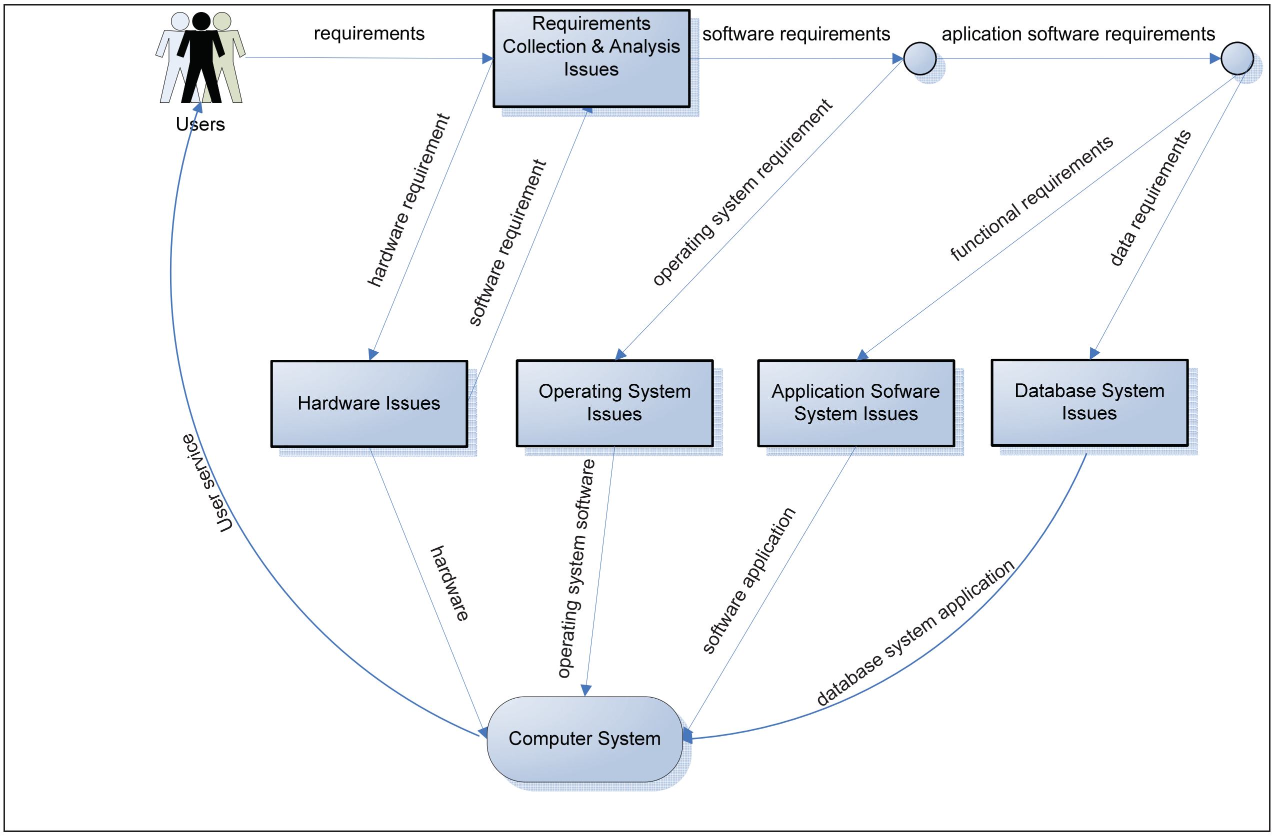


Figure 3. Concept map for Introduction to Computer Engineering course

These requirements triggers the system parts needed to be developed which will be the answer of the second question. We defined these system parts related to the following issues:

- Hardware Systems
- Operating Systems
- Application Software Systems
- Database Systems

We built the connections between those system parts related to system requirements as shown in Figure 3. The integration of those parts will establish the computer system, which is expected to serve the user requests.

Technology, all the theory and developments produced in this area is for the human beings. Main purpose is to provide support for them to work easily, quickly and effectively. Therefore, when the students, they are expected to provide solutions for computer systems to provide support to users. Additionally, they can work in academy to develop new theories, methods, and tools for this field. Accordingly, *user requirements* drive the studies in this field. Hardware requirements trigger new theories, technologies, methods, and products in this field. For this purpose, students should understand the *hardware system issues*. Therefore, in the curriculum of the computer engineering programs, we have several courses addressing main issues of the hardware type studies in this field. Accordingly, in the introduction to computer engineering course the basic hardware concepts are summarized. On the other hand, software requirements may be about the application software or operating software. In order to understand these concepts, one should understand how the application software and operating system software issues are handled. In the concept map, *operating system issues* and *software system issues* provide these concepts. These cover a broad range of design, development, and implementation, management of these systems, and their theories and methods.

The application software requirements are characterized as data and functional requirements. The data requirements triggers *database system issues*, which includes concepts like database management systems, file organization, database design, development, administration, optimization, and monitoring. Functional requirements generate *Software System issues* which cover a wide range of topics like software design, development, testing and management.

All the theories, products, and technologies related to the above-mentioned issues are integrated to construct a *computer system* to better serve for the end users. Based on the requirements, the end user can be able to get services from the computer systems.

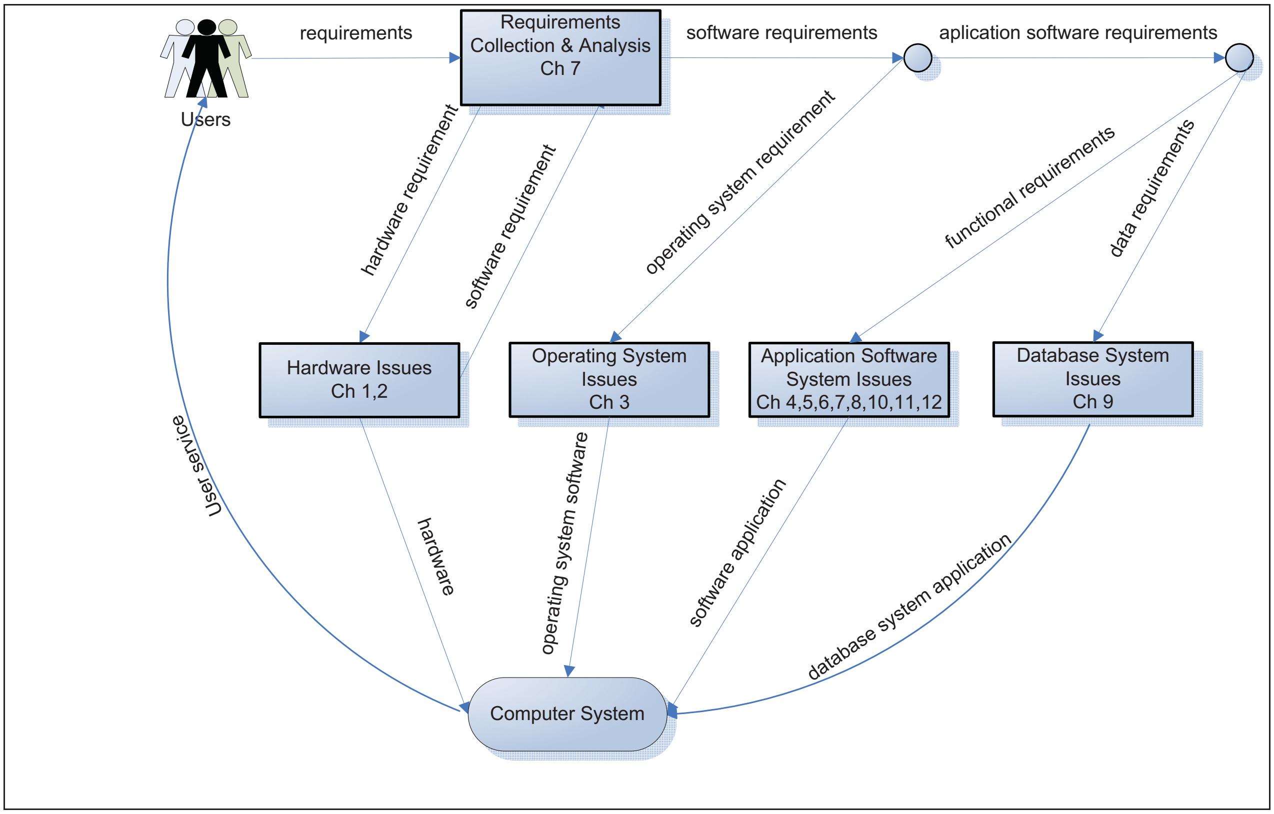


Figure 4. Concept Map- course content match

After we have developed the concept map for the course, we have mapped the chapters covered in the course with the concepts stated in the concept map as described in Figure 4. This shows that every topic covered in the course has a corresponding item in the concept map, which expresses the need for a computer system in the real world.

Describing the concept map to students at each step of the course would make them visualize the big picture and recognize the connection of different concepts they will learn in detail in their curriculum. this way, they can link their previous knowledge, with the new subject which will create a meaningful learning for them.

Additionally, we mapped the concept map with computer engineering curriculum as illustrated in Figure 5. This figure has two important results.

First, it reveals the distribution of the courses in the curriculum based on real world system requirements.

We believe that, the computer engineering issues covered in the curriculum should give insights to the students and make them realize the need for those systems in real world that motivates usage or development of computer systems in the real-life processes. They should be able to map the practical and theoretical aspects of the concepts they learn, to the real world entities where these concepts are employed.

Secondly, this map provides valuable measure to assess how much the program mission is reflected in the curriculum as well as detecting the related problems and improvements of the curriculum.

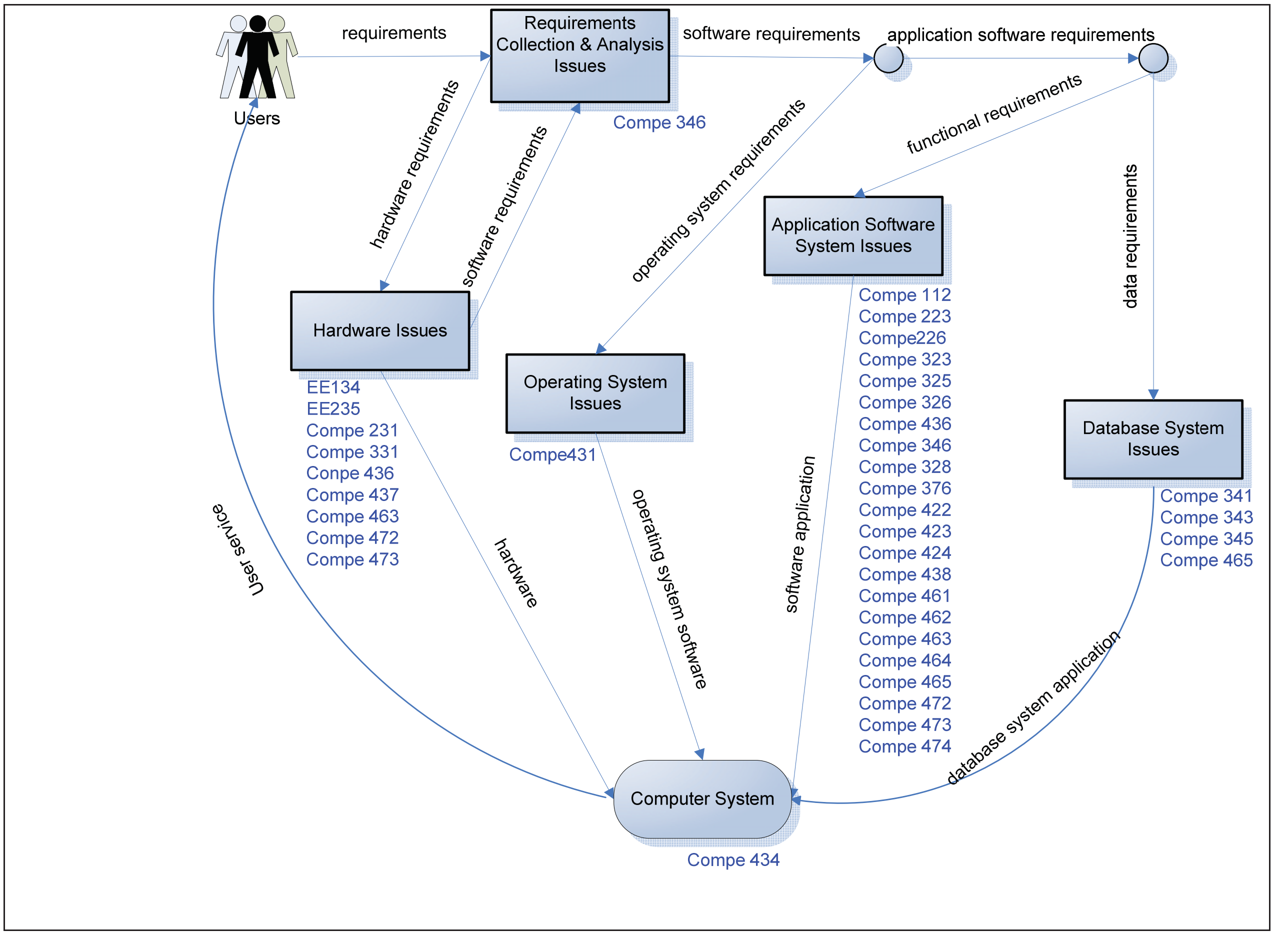


Figure 5. Concept Map –curriculum match

V. DISCUSSIONS AND CONCLUSIONS

In this study, we have addresses two main problems of the field o f Computer En gineering ed ucation: complexity of the introduction to Co mputer En gineering cou rses and t he Computer En gineering curriculum. to address these problems a concept map approach is employed. For development of the concept map a n ovel ap proach "Goal-Qestion-Concept" method has been applied.

The proposed concept maps possibly have several benefits for the Computer Engineering education programs. First, they can address the co ncepts o f In troduction to Co mputer Engineering course wh ich provides a clear v iew of the f ield for freshmans. Secon dly, th e co ncept map and curriculum match diagram helps students to address each course of their curriculum, with their c onceptual view pr ovided f or t he introduction co urse. th is h elps th em to relate their gen eral knowledge of the domain with the courses they will take.

Additionally, lower level concept maps can be prepared for each course and the sam e concept map and curriculum match diagrams can be applied to t he lower l evel, detail ed co urse contents. This wa y, st udents may master t he de tails o f t he field without getting lost in the complexity of the field.

We believe th at, if the s tudents ar e introduced with these concept maps at the beginning of each course, addressing the position of that cou rse in the co ncept m ap, t hey will build connections between the topics of the area effectively.

As a fu ture stud y, these concept maps sho uld be decomposed and detailed to lower levels and applied for each course. T he b enefits o f th is new ap proach f or the computer engineering programs should be evaluated pedagogically. We believe this approach can be applied to any discipline.

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APPENDIX

Curriculum of Computer Engineering Department

COMPE 111-Intro. Computer Engineering
COMPE 112-Computer Programming in C
CHEM 102 - General Chemistry
E 101 - Engineering Fundamentals
ENG 111 - Introduction to Communication Skills
ENG 113 - Academic Listening and Note-taking
MATH 151 - Calculus I
PHYS 101 - General Physics I
EE 134 - Circuit Analysis
ENG 104 - Communication Skills II
MATH 152 - Calculus II
PHYS 102 - General Physics II
EE 235 - Digital Electronics
ENG 211 - Communication Skills III
MATH 275 - Linear Algebra
ENG 212 - Technical Report Writing&Communication
IE 220 - Probability and Statistics
MATH 276 - Differential Equations
TURK 101 - Turkish Language I
COMPE 251- Discrete Computational Structures
COMPE 231- Digital Circuits and Systems
COMPE 223- Object Oriented Programming
COMPE 236- Intro. to Microprocessors&Microcontrollers
COMPE 226- Data Structures
IE 305 - Engineering Economic Analysis
TURK 102 - Turkish Language II
HIST 101 - Principles of Atatürk and the History of Turkish Revolution I
HIST 102 - Principles of Atatürk &History of Turkish Revolution II
ORY 400 - Social and Cultural Activites
COMPE 341- Database Design and Management
COMPE 331- Computer Architecture and Organization
COMPE 325- Study of Programming Languages
COMPE 323- Algorithms
COMPE 350- Numerical Methods
COMPE 346- Software Engineering
COMPE 326- Formal Languages And Automata
COMPE399- Summer Practice I
COMPE 499 - Summer Practice II
COMPE 491- Senior Project I
COMPE 431- Operating Systems
COMPE 492- Senior Project II
COMPE 436- Data Communications & Networks
COMPE 328- Object-Oriented Analysis and Design(TE)
COMPE 343- Database Systems & Programming (TE)
COMPE 345- Data Warehousing&Business Intelligence(TE)
COMPE 376- Computer Games and Simulation (TE)
COMPE 422- Visual Programming (TE)
COMPE 423- Logic Programming (TE)
COMPE 424- Language Processors (TE)
COMPE 434- Embedded System Design (TE)
COMPE 437- VLSI Design (TE)
COMPE 438- Java Programming(TE)
COMPE 461- Applied Neural Computing (TE)
COMPE 462- Artificial Intelligence (TE)
COMPE 463- Digital Signal Processing (TE)
COMPE 464- Pattern Recognition&Image Processing (TE)
COMPE 465- Knowledge Engineering (TE)
COMPE 472- Parallel Computing (TE)
COMPE 473- Computer Graphics (TE)
COMPE 474- Soft Computing (TE)

Session 02A Area 3: Skills Development: Technical Writing, Presentation, Teamwork

Challenging Students' Responsibility: An Engagement Methodology
Soto-Merino, Juan Carlos
University of the Basque Country UPV-EHU (Spain)

Analyzing self-reflection by Computer Science students to identify bad study habits
Guerreiro, Pedro; Sustelo, María Filomena dos Santos
UALg (Portugal)

Assessing Competency in Undergraduate Software Engineering Teams
Devlin, Marie; Phillips, Chris
Newcastle University (United Kingdom)

Challenging Students' Responsibility:

An Engagement Methodology

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Dept. of Applied Mathematics
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Bilbao, Spain
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Abstract— **In order to challenge the students' responsibility, motivation and participation in mathematics courses this paper reports an action-based research about some ways to tackle such tasks for increasing their motivation and course engagement from a "teamwork" competence. Their comments and suggestions provide strategies to improve the results obtained.**

Keywords: Competences, Formative Assessment, Rubric, Student's Opinion, PBL/EBL, Teamwork

	Students	Percentage	Mean
Don't succeed		74,92	
Electricity	7,00	2,17	3,37
Industrial Electronics	27,00	5,34	4,13
Industrial Chemistry	6,00	1,09	4,18
Mechanics	32,00	9,18	3,09
Management Informatics	20,00	7,30	3,95
Total	92		3,67

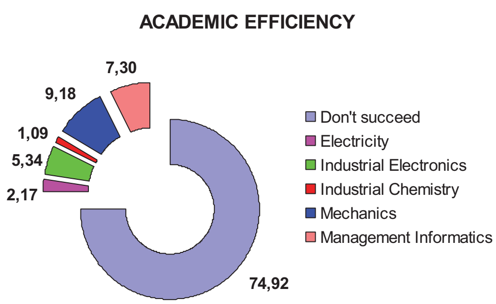


Figure 1. Outcomes of a prerrequisite validation.

I. STATE OF THE ART

On the one hand, several studies have analyzed the state of the art in the curriculum of Mathematics. On the other, it has been observed that our civilization is experiencing the "impact of a regression to the mean". Namely, the quality of the learning/teaching process (LTP) in Mathematics in students entering the university is in decline; for most students the mathematical maturity is achieved (from nursery to school) more as a product of random events outside the family environment; it should require a more rigorous mathematics education programs in compulsory and secondary school; there is a clear difference between 'mathematical thinking" and "the process of calculating"; as calculators, while excellent tools for many things, do not imply the development of resolution and reasoning strategies; … [4, 15]. For instance, when first-year students tried a mathematical prerequisite test on undergraduate contents they do not succeed (Figure 1). This study has been done at the very beginning of this course to test the mathematics mean level of 92 students entering our School. That questionnaire involves multiple-choice answer easy questions on calculus, algebra and statistics (Figure 2). Also, at the very beginning of this course a literacy study has been implemented with the students, that this year were entering the university for the first time. This short test includes numerical, schematic and written knowledge for information in prose, considered from a basic competence point of view [13]. Results have been discouraging: the mean label attained has been label one out of five (see Figure 3), although the sample studied has not been valid from a statistical consideration (the sampling error being 4.28 %). Namely, 90 % of the students do not reach level 3, which is considered the minimum desired following the international conventions.

C13. Let us assume the the following polynomial. Which is the greatest common divisor?

$p_1(x)=(x^2+1)(x-3)(x+2)(x+1)$
$p_2(x)=(x-4)(x-1)(x+1)$
$p_3(x)=(x-3)(x-2)(x-1)^3(x+1)^3(x+2)$
$p_4(x)=x^2-x-2$

1.	O	$p_4(x)$	**NS NC**
2.	O	$(x-3)(x+2)(x+1)$	
3.	O	$(x+1)$	
4.	O	$(x-3)(x+2)$	
5.	O	$(x-2)(x+1)$	
6.	O	x^2-x-2	
7.	O	1	

Figure 2. Example of the prerreqisite questionaire.

In addition, many students are not successful in developing their LTP. There is a misconception about the work method to be developed in university environments (especially in mathematics). Our students are generally not successfully developing appropriate skills and capabilities to achieve the strategic objectives for [10]. Furthermore, the Bologna Declaration has set the challenge to improve education, research and management schemes in the European Higher Education Area (EHEA), because in the corresponding curriculum the student is considered as an overall planning process. Consequently, they should expect rapid change (but hopefully not accelerated). The task-based LTP will become obsolete. The student, not the teacher, is the goal of the curriculum and the teacher becomes now a guide (in the sense of an adviser to him or a coach). Finally, but equally important, the New Information and Communication Technologies suggest future changes in climate to be given to the curriculum. That is, they bring different tools to assist the teacher in the development of any LTP. Learning and mastering these tools will help the teacher to have more resources to address the aforementioned failure. The three referred causes suggest that this might be a good time for a rethinking of the basic principles that guide the LTP from a teacher's viewpoint, so that if using the experience gained so far, there is a process of self-reflection and self-criticism to analyze and correct those weaknesses and along with the strengths observed, so as to improve in the quality of the educational process. An adequate approach is provided from the research-action methodology [8].

LITERACY						
LEVEL 1			LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
0-125	126-175	176-225	226-275	276-325	326-375	376-500
N1			N2	N3	N4	N5

LEVEL	NUMBER OF PERSONS	PERCENTAGE
< LEVEL 1	0	0 %
LEVEL 1	14	66 %
LEVEL 2	5	24 %
LEVEL 3	2	10 %
LEVEL 4	0	
LEVEL 5	0	
MEAN LEVEL	LITERACY MEAN LEVEL	
	N1	

Figure 3. Results of the Literacy short test.

In the year 2010 the Bologna process (namely, EHEA) will be completed in the Spanish universities: changes in learning and teaching, in institutional and management levels. To improve the competitiveness of universities and the quality of higher education in the European Union curricula will be worked based on the professional responsibilities /academic competences, the student's active and ongoing learning, the flexibility and the internationalization of studies, the introduction of the European Credit for Transfer and Accumulation (ECTS), the alignment of curricular structures in two cycles and the people's mobility. The graduate profile will be a benchmark reference of the new curriculum, which is being designed at present in the Spanish university, because it will have to establish the core (basic) competences (standards for learning to learn and learning to know), crossed competences (learning to live together and learning to be), and specific competences (learning to do). That new curriculum will develop the spirit EHEA/ECTS: a Long-Life-Learning development profile of the student through a development of competences (i.e., skills, attitudes, aptitudes and values –the competence viewpoint).

As a consequence, changes are expected in the educational methodologies and in the assessment and accreditation processes of the syllabus [14]. Formative assessment will have to be emphasized since: it facilitates the development of self-assessment (reflection) in learning; it encourages teacher and peer dialogue around learning; it helps clarify what good performance is (goals, criteria, expected standards); it provides opportunities to close the gap between current and desired performance, it delivers high quality information to students about their learning; it encourages positive motivational beliefs and self-esteem; and, it provides information to teachers that can be used to help shape the teaching [7, 12]. This paper reports an experience where assessment is used to engage student's motivation, responsibility and participation using rubrics as valuation tools.

UNIT	ENGINEERING STATISTICAL METHODS 5 ECTS	WEIGHT (%)	
1	Introduction to Statistics	3.33	33.33
2	Descriptive Statistics	10.00	
3	The Theory of Probability	6.67	
4	Probability Models	13.33	
5	Introduction to Quality Control	6.67	45.00
6	Parameter Estimation, Hypothesis Contrast and Model Contrast	28.33	
7	Regresión and Correlation Theory	10.00	
8	A PBL Project of applied orientation	21.67	21.67

- ⌘ **C1:** To determine in detail from a theoretical/numerical perspective the key elements of deductive and inferential Statistics. Based on the contents of the subject, general strategies must be significantly implemented to get involved in the resolution of engineering problems and related matters.
- ⌘ **C2:** To derive and analyse the information inherent in a given statistical series (significant random sample), by means of numerical/symbolic computations. The use of some scientific software (SPSS, R, Mathematica, and / or Excel) of interest in engineering and applied sciences is needed. Simple examples are planned and solved, analyzing the error attributable to the process developed and studying the relationships with situations, in which students usually will find in engineering environments.
- ⌘ **C3:** To develop statistically valid conclusions in a critical way (reasoned and justified) from the results produced, that are based on an efficient management of information acquired.
- ⌘ **C4:** To cooperatively plan and develop in a coherent way a simple research paper on any contextualized chemical situation, including an oral presentation and/or written essay that describes the main steps in the implementation completed. The most relevant facts and findings must be highlighted, while verifying the management of the resources used (people, media, mathematical programs, times, concepts, ...), which the working team/group has necessitated (from a multidisciplinary perspective).
- ⌘ **C5:** To acquire working strategies and mechanisms to promote the continuing need to improve a meaningful learning throughout life, worrying about the quality of the accomplishments, making particular use of computer management through ICTs, focusing on rigor, precision and excellence.

Figure 4. The syllabus: a) The main contents; b) the core competences of the syllabus.

II. PROBLEM STATEMENT

Several studies have shown that the characteristics of the classes usually rated by the students include great challenge, but full opportunity to review and improve their work before they are qualified and, therefore, to learn from their mistakes in the process [3]. One of the advantages of the formative assessment is that it does fit simpler procedures than those used in traditional exams as outlined for summative assessment. Valuation matrices (or rubrics) are scoring guides used in assessing student's performance that describe the specific characteristics of a product, project or task at various levels of performance, in order to clarify what is expected of the student's work, assess their implementation and facilitate the feedback supply [1, 11]. Students get bored at grading [2, 16]. How can the teacher deal with this environment? This paper reflects over way to engage (in an action-research environment) undergraduates in motivation, participation and responsibility tasks challenges, since they are not accustomed to work such competences. Besides, such values are rarely treated in the first and second courses of the any university degree. That is, it is reported how to challenge students in mathematics courses, taking into account the comments provided in the preceding section.

Each course the students must complete in cooperative groups a research about a statistical problem related to the most important descriptors and contents of the syllabus (see Competence 5 in Figure 4). Consequently, the student must deal a great deal of skills that define such team-work competence: cooperative work, communicative strategies, effective meetings, tutorial reinforcement, resource management optimization, team work (of course), facilitation and supervision, and assessment, among many others. It is a quite complex competence [6, 7, 9].

The students have been proposed to get involved in all the stages of the preparation of an assessment tool for accreditation of one of the syllabus competence (i.e., team work). Figure 4 shows the structure of the course syllabus; namely, credit weight and key competences. Such a process has included: **a)** a questionnaire to decide the evaluation criteria for formative and summative assessment that would be considered in the competence rubric; **b)** a proposal to pose the quantification of the criteria applied; **c)** the use of that tool in the formative assessment to other groups; **d)** the use of the rubric to look for evidences to be added to his/her portfolio to produce the summative self-evaluation, which is discussed with the teacher at the end of the course; **e)** to provide both qualitative and quantitative justifications and reasoning about the opinion of the results obtained; and **f)** as a consequence, an improvement strategy has been derived to be applied next time.

This study is part of a cross-sectional study of a team of educational innovation (TEI) conducted in five degrees on the student's opinion regarding the competence of "team work." It includes public and private universities of the Basque Country land: 5 faculties, 6 degrees and 8 researchers are included. Here, the results of a statistics course (2nd year in a 3-year degree on Industrial Engineering where multiple teaching methodologies are used surrounding the PBL/EBL (Problem Based Learning / Enquire Based Learning) approach) will be presented and discussed (Figure 4 shows its main characteristics).

III. METHODOLOGY

The methodology has implied the following steps:

(1) Analysis of the evaluation indicators and assessment criteria, which must be considered in a given course.

(2) The assessment rubric has been designed and implemented.

(3) The rubric has been applied in the formative and the summative stages of the assessment. Also, it has been applied to valuate the product of each group, which has been presented at a conference poster session type.

(4) The process has been evaluated looking for the students' comments and valuation, altogether with the professor's considerations.

		IMPORTANCE		COURSE	
		Mean	St. Deviation	Mean	St. Deviation
Structure/ Estructura	Ability to plan and organize work *Capacidad de planificar y organizar el trabajo*	2,56	0,58	2,51	0,63
	Organize and prioritize tasks *Organizar y priorizar las tareas*	2,38	0,65	2,31	0,67
	Ability to engage and work together *Habilidad para implicarse y trabajar en equipo*	2,28	0,61	2,25	0,64
	Willingness to work *Disposición para el trabajo*	2,36	0,70	2,34	0,73
	Level of content acquisition and transmission to their partners *Nivel de adquisición de los contenidos y transmisión a sus compañer@s*	2,04	0,61	1,99	0,62
	Participate in various activities *Participar en las diferentes actividades*	1,96	0,68	1,94	0,71
	Study habits *Hábitos de estudio*	2,60	0,58	2,59	0,63
	Resposibility *Responsabilidad*	2,72	0,61	2,68	0,67
	Autonomous learning *Aprendizaje autónomo*	2,36	0,57	2,29	0,60
	Solutions for learning difficulties *Busca soluciones a los problemas de aprendizaje*	2,52	0,65	2,51	0,69
	Ability to adapt to new situations *Capacidad para adaptarse a nuevas situaciones*	2,32	0,56	2,20	0,63
Implementation/ Procedimiento	Attendance at meetings *Asistencia a las reuniones*	2,44	0,65	2,42	0,75
	Having clear and shared work goals *Tener claros y compartir los objetivos del trabajo*	2,44	0,58	2,33	0,68
	Development of the task *Desarrollo de la tarea*	2,20	0,58	2,07	0,62
	Meet standard/agreed norms *Cumplir las normas establecidas/pactadas*	2,40	0,76	2,38	0,84
	Contribute to the tasks assigned by the group *Contribuir en las tareas asignadas por el grupo*	2,56	0,65	2,55	0,75
	Meeting the agreed schedule of tasks *Cumplir el cronograma de tareas acordado*	2,08	0,64	2,03	0,72
	Undertake tasks / roles in terms of objectives *Asumir tareas/roles en función de los objetivos*	1,84	0,69	1,77	0,74
	Efficient management of resources using the group work *Gestión eficiente de los recursos de trabajo que usa el grupo*	2,04	0,68	1,99	0,68
	Keeping colleagues informed and share all relevant information *Mantener a los compañeros informados y compartir toda la información relevante*	2,64	0,57	2,59	0,69
	Effective meetings: capacity for organization and planning *Reuniones eficaces: capacidad de organización y planificación*	2,36	0,49	2,24	0,59
Relationships/ Relaciones	Interact positively with the rest of the group *Interrelacionarse de forma positiva con el resto del grupo*	2,56	0,77	2,51	0,79
	Communicating effectively (orally and in writing) with the other students *Comunicarse de forma efectiva (oral y por escrito) con los otros compañeros*	2,36	0,57	2,29	0,67
	Contributions made to the project and the work team *Aportaciones realizadas al proyecto y al equipo*	2,40	0,50	2,29	0,61
	Participate actively in the work of the group and make significant contributions *Participa activamente en las tareas del grupo y hace contribuciones relevantes*	2,16	0,62	2,12	0,65
	Meeting the commitments made *Responder a los compromisos adquiridos*	2,40	0,65	2,38	0,68
	Solve problems that arise *Resolver los problemas que surjan*	2,36	0,64	2,33	0,67
	Leadership and initiative *Liderazgo e iniciativa*	1,76	0,60	1,72	0,63
	Ask for ideas and opinions for the decisions and plans *Solicitar ideas y opiniones para la toma de decisiones y planes*	2,08	0,64	1,99	0,62
	Cooperation *Cooperación*	2,52	0,59	2,50	0,63
	Putting the group's goals for personal interests *Anteponer los objetivos del grupo a los intereses personales*	2,08	0,70	1,99	0,74
	Integrating those not participating *Integrar a los que no participan*	2,12	0,78	2,08	0,73
Emotions/ Emociones	Ability to express, empathize and communicate emotions *Capacidad para expresar emociones, empatía y comunicarse*	1,92	0,81	1,91	0,84
	Group dynamics *Dinámica grupal*	2,20	0,58	2,16	0,67
	Promoting healthy disagreement and debate, working consensus. Constructive criticism *Fomentar el sano desacuerdo y el debate, trabajando el consenso. Hacer crítica constructiva*	2,36	0,76	2,30	0,77
	Publicly recognize the achievements of others *Reconocer públicamente los logros de los otros*	2,08	0,81	2,00	0,84
	Rate equally the point of view and opinions from all members of the group *Valorar por igual la opinión de todos los componentes del grupo*	2,64	0,64	2,59	0,68

Evaluation/ Evaluación	Assume one's responsibility for its results *Asume su responsabilidad sobre sus resultados*	2,52	0,71	2,51	0,74
	Evaluate one's skills and own position in the group *Evalúa sus capacidades y su propia situación en el grupo*	2,16	0,62	2,07	0,68
	Co-evaluation between components on the involvement of each member *Coevaluación entre los componentes respecto a la intervención de cada miembro*	1,83	0,70	1,81	0,67
	Monitoring the process of group work by the faculty *Supervisión del proceso del trabajo del grupo por parte del profesorado*	2,20	0,82	2,17	0,83
	Assessing the group's final outcomes *Valoración de la producción final del grupo*	2,40	0,71	2,42	0,74
		2,29		2,24	

Figure 5. The students' decision about the assessment indicators of the team-working competence (over 4 points).

(5) An improvement planning has been retrieved as the final outcome, where corrective, preventive and/ or improvement actions have been taken into account.

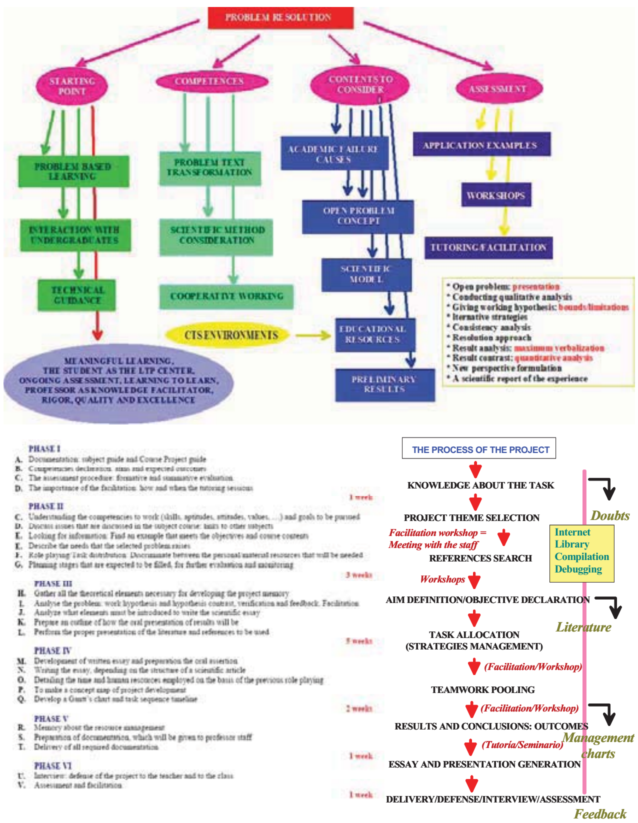


Figure 6. Problem/Project solving via a PBL/EBL approach.

The TEI has carefully considered the knowledge, abilities, skills, values, attitudes, aptitudes and virtues that can define this competence. At last, four affinity groups (evaluation criteria) with a total of 42 evaluation indicators have been produces; namely, the structure of the group (11 items), the process generated (10 items), the relations established (11 items), the appeared emotions (5 items) and the assessment itself (5 items). The students have chosen (Figure 5 shows the results of the syllabus reported in Figure 4) what items must be included in a given course (last two columns) and have decided its relative importance (first two columns) in the whole of the competence environment. Columns 1 and 3 are mean values and columns 2 and 4 are standard deviations. The mean values reported show that students think that the mean importance of this competence is 2.29 (out of 3) while the mean course is 2.24 (out of 3). In other words, the importance assumed is high and students suggest that this competence must be developed in the upper courses of the degree. To challenge this situation some explanations are necessary to engage the students, because they are accustomed to play a little role on the daily discourse of the LTP.

25 students (over 36 –that attend class regularly; i.e. 69.44 %) have answered the questionary. However, 15 students (29.41 %) did not go regularly to class: they were matriculated but they were not going to class.

Then, an analytic valuation matrix has been defined (see the Figure 14 at the end of this paper). It contains five evaluation criteria: the general situation of the (5 evaluation indicators); the procedures implied in the group development (6 items); the relationships between the group members (4 items); the treatment of the emotions that have appeared (3 items), and the assessment process (4 items). Three competence levels have been only established: "quite competent" (2 marks), "only acceptable" (1 mark) and "does not fulfil" (the task or so must be redone again). Each student has applied this tool regularly as formative assessment to decide where the group does not fulfil the necessary requirements to be competent as team work or where the group must improve its development to play the role of a real group. However, each student has token this rubric into account to analyse his/her contribution to the general development of the group itself or to analyse how the group was helping him to grow up as a person. These reflections are evidences for the portfolio that can be used to explore the performance of the student's evolution over the subject competences. As it has been mentioned, at the beginning of the course the evaluation criteria are discussed with the students and some consensus is reached. Then, each team evaluates its work which is discussed with the professor in an interview (inner evaluation) and the remaining teams do evaluate the oral presentation, which must be given (outer evaluation) in the general context of a PBL/EBL approach (Figure 6). Otherwise, the student has an opportunity to fix the minimum quality of the production result the group will have to develop, and, at the same time, there exists a non-explicit level to show the group where the excellence level is located.

It has been noticed that the team work competence must be approached quite differently at first courses or in the last ones during the implementation of the PBL/EBL methodology. Because of that, facilitation and supervision are peremptory [6]. When developing a PBL/EBL Project course great care must be devoted to the tutoring task, above all in the first courses (namely, this is the case where strengthening work in basic sciences is called for [7]); namely, focusing on improving the student's communication [9]. In this sense, facilitation must develop daily reflection: pre-session (to present a focus concerning group dynamics so that facilitative questions should be used to start reflection), ordinary supervision session (with timeouts to discuss focus and to play diverse roles) and post-session (to facilitate reflections on the focus). Furthermore, facilitation implies tutoring and supervision (sometimes, even control) to respond to student's problems in terms of meta-skills [5, 7] (see Figure 7). Several dimensions are taken into account: the intellectual dimension, the personal dimension, the social dimension, the practical dimension (with several viewpoints: providing support, encouraging independence, developing the interpersonal) and assessing research (formative assessment, creativity and originality, reliability and validity) [9, 16].

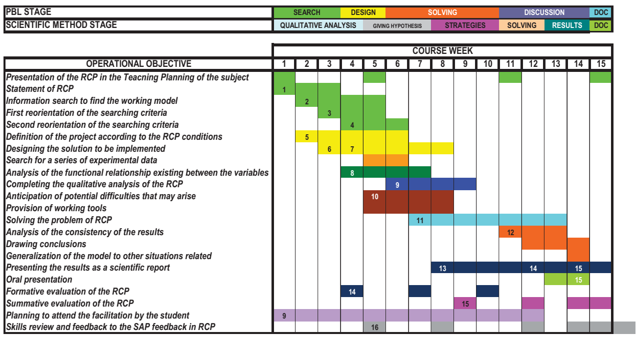


Figure 7. A Gantt's diagram of the Course Project timing.

However, the teacher's role must also be considered from a leadership point of view: from hierarchy / autocratic / consultative to autonomy / functional / contractual via cooperation / negotiation / consultative. This implies that the student/teacher relationships ought to include six dimensions: the planning dimension (goal-oriented, aims, ends and means), the meaning dimension (cognitive understanding of experience), the confronting dimension (raising awareness to individual and group resistance), the feeling dimension (addressing emotional competence and incompetence), the structuring dimension (methodology of structuring experiences) and the valuing dimension (creating a support climate that celebrates individuals) [6, 12].

This research is action-oriented (see Figure 10); so, a Deming's wheel (a Plan-Do-Act -Check cycle) must be reconsidered once again. That is, the design and the implementation being developed mechanisms and tools to look for information about the results and about the address of the research must be considered. In order to know the students' opinion a half-opened questionnaire has been given to the students (Figure 8). The following topics are considered to attain the student's point of view on the approach, development, evaluation and analysis of the team work competence. Specifically, the elements taken into consideration cover the information supplied, the initial training, the degree of initial expectation with respect to the competence itself, the degree reached in its development, the development of the teaching methodology applied, the facilitation/supervision/tutoring set up and the assessment considered.

Remembering, the result of this teaching task is to produce a scientific essay in a cooperative environment (Figures 6 and 7). So, the own subject questions the student about the contribution of this competence (see Figure 9) related to all the another competences, because its weight is 21.67 % (Figure 4). Students also write some comments in the portfolio about their viewpoints on this approach, which are given in the interview at the end of the course when they explain the evidences carried out in their portfolios.

IV. RESULT DISCUSSION

Formally, these results demonstrate the need and urgency that the students show to introduce (early) this competence in their studies (Figure 5). Students are quite surprised by what they have been presented with this methodology. All the students that have answered the questionnaires were involved in this approach, but since they were not all of the students of this subject results are not conclusive. However, this sample includes the 84.45 % of the students who went to class.

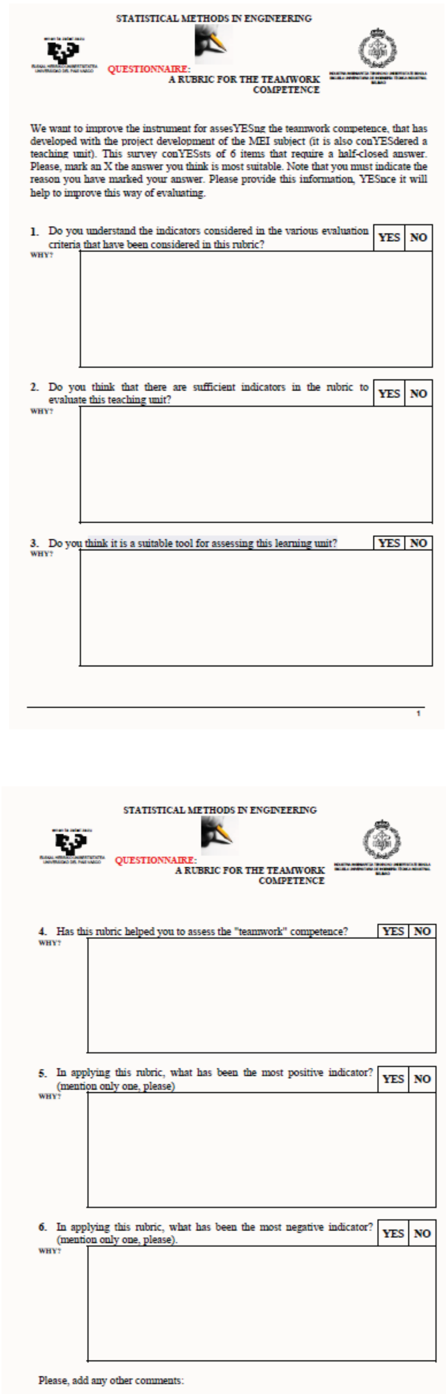
Applying this strategy, all the existing groups have succeed in their marks because they have fix beforehand a reference level to surpass in the assessment rubric (it has been degree 1 in the evaluation indicators –see the rubric at the end of the paper). Table I provides high positive answer percentages to the questions of Figure 8. In particular the most voted evaluation indicator is "21 - Evaluation modes" and the most negative "17 - Conflict resolution" in the rubric applied, because students didn't well understand it –they added in the comments at the end of the questionnaire. There is great agreement with this methodology (87.65 %) but feedback has produced interesting ways to deep in (see this section below).

TABLE I. RESULTS OF THE STUDENT'S OPINION QUESTIONNAIRE

ITEM	EXPLAINATION	Percentage	¿WHICH?
1	**The assessment criteria understanding**	95,13	
2	**The assessment criteria sufficiency**	98,83	
3	**Evaluation tool adequacy**	82,03	
4	**The rubric has been useful**	82,36	
5	**The evaluation indicator most voted**	91,23	21,00
6	**The evaluation indicator most negative**	65,23	17,00
	Mean value	**87,65**	

Table II summarizes the overall performance mean rates of this research, which the students have directly answered for. All responses ranged from zero to ten points. The general opinion about the methodology deployed is good (7.2 points), and students like the syllabus (7.6 points), but improvements can be carried out. The competences and objectives of the course are well understood (8.1 points); however, the competence here researched has dealt with difficulties (6.5 points) because the way has been worked out is a bit difficult to be followed (the students have said). Moreover, the motivation rate is good (7.8 points) but the participation index provided has been excellent (9.1 points), but problems have arise because of the responsibility indicator is not so good (7.3 points). The students demand a lot of help and care (though they are in first courses) –self-sufficiency index is 6.2 points, while they have considered an excellent level of facilitation (8.9 points), too.

The methodology implemented in Section III provides a protocol to be applied to engage students in the LTP of the syllabus, wh ere a practical learning is set do wn. B ut t his strategy implies to look after alliances with students analyzing very carefu lly tho se sy nergies th at usually appear in c lass. Results are qui te good (m ean val ues of Ta bles I and II) and they in vite to use th e PBL a pproach. However, th ese resu lts can be improved, and the students can help in such a task. The comments provided but students have declared and pointed:


STATISTICAL METHODS IN ENGINEERING

QUESTIONNAIRE:
A RUBRIC FOR THE TEAMWORK COMPETENCE

We want to improve the instrument for assesYESng the teamwork competence, that has developed with the project development of the MEI subject (it is also conYESdered a teaching unit). This survey conYESsts of 6 items that require a half-closed answer. Please, mark an X the answer you think is most suitable. Note that you must indicate the reason you have marked your answer. Please provide this information, YESnce it will help to improve this way of evaluating.

1. Do you understand the indicators considered in the various evaluation criteria that have been considered in this rubric? YES | NO
WHY?

2. Do you think that there are sufficient indicators in the rubric to evaluate this teaching unit? YES | NO
WHY?

3. Do you think it is a suitable tool for assessing this learning unit? YES | NO
WHY?

1

STATISTICAL METHODS IN ENGINEERING

QUESTIONNAIRE:
A RUBRIC FOR THE TEAMWORK COMPETENCE

4. Has this rubric helped you to assess the "teamwork" competence? YES | NO
WHY?

5. In applying this rubric, what has been the most positive indicator? (mention only one, please) YES | NO
WHY?

6. In applying this rubric, what has been the most negative indicator? (mention only one, please). YES | NO
WHY?

Please, add any other comments:

Figure 8. A questionnaire about the student's viewpoint.

(1) as **strengths**: the novelty of t he methodology, the variety of teach ing meth odologies involved, the facilitat ion prov ided and the student's implication, and

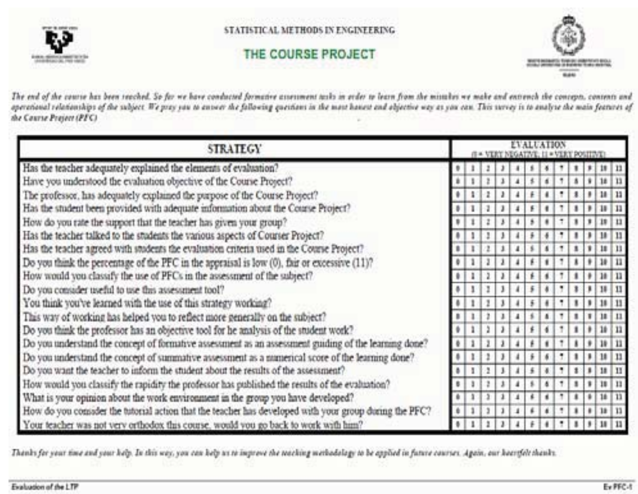
(2) as **weaknesses** of t his implementation: the har dness test, the existence of a lot information, a lot of work to be made by the student (specially that one off-class) and the peer to peer coevaluation.

The students themselves suggest some activities to cope for an **improvement planning**, as feedback:

(1) As **improvement actions** th ey propose: to reduce th e quantity of in formation and to apply other forms to ch allenge them.

(2) As **corrective actions**, t hey pr oposed dee p i n the explanation of th e stud ent's respon sibility an d what th e student is assumed to produce as final outcomes, or to provide specific examples of similar results or portfolios.

(3) As **preventive actions**, they press to give greater freedom and to use spe cific examples of the syllab us instead of being them th emselves to look for them. They are also c oncerned that this way of working implies great job, in exchange for a far more profitable, but in the long term.


STATISTICAL METHODS IN ENGINEERING

THE COURSE PROJECT

The end of the course has been reached. So far we have conducted formative assessment tasks in order to learn from the mistakes we make and entrench the concepts, contents and operational relationships of the subject. We pray you to answer the following questions in the most honest and objective way as you can. This survey is to analyse the main features of the Course Project (PFC)

STRATEGY	EVALUATION (0 = VERY NEGATIVE, 11 = VERY POSITIVE)											
Has the teacher adequately explained the elements of evaluation?	0	1	2	3	4	5	6	7	8	9	10	11
Have you understood the evaluation objective of the Course Project?	0	1	2	3	4	5	6	7	8	9	10	11
The professor, has adequately explained the purpose of the Course Project?	0	1	2	3	4	5	6	7	8	9	10	11
Has the student been provided with adequate information about the Course Project?	0	1	2	3	4	5	6	7	8	9	10	11
How do you rate the support that the teacher has given your group?	0	1	2	3	4	5	6	7	8	9	10	11
Has the teacher talked to the students the various aspects of Courser Project?	0	1	2	3	4	5	6	7	8	9	10	11
Has the teacher agreed with students the evaluation criteria used in the Course Project?	0	1	2	3	4	5	6	7	8	9	10	11
Do you think the percentage of the PFC in the appraisal is low (0), fair or excessive (11)?	0	1	2	3	4	5	6	7	8	9	10	11
How would you classify the use of PFCs in the assessment of the subject?	0	1	2	3	4	5	6	7	8	9	10	11
Do you consider useful to use this assessment tool?	0	1	2	3	4	5	6	7	8	9	10	11
You think you've learned with the use of this strategy working?	0	1	2	3	4	5	6	7	8	9	10	11
This way of working has helped you to reflect more generally on the subject?	0	1	2	3	4	5	6	7	8	9	10	11
Do you think the professor has an objective tool for he analysis of the student work?	0	1	2	3	4	5	6	7	8	9	10	11
Do you understand the concept of formative assessment as an assessment guiding of the learning done?	0	1	2	3	4	5	6	7	8	9	10	11
Do you understand the concept of summative assessment as a numerical score of the learning done?	0	1	2	3	4	5	6	7	8	9	10	11
Do you want the teacher to inform the student about the results of the assessment?	0	1	2	3	4	5	6	7	8	9	10	11
How would you classify the rapidity the professor has published the results of the evaluation?	0	1	2	3	4	5	6	7	8	9	10	11
What is your opinion about the work environment in the group you have developed?	0	1	2	3	4	5	6	7	8	9	10	11
How do you consider the tutorial action that the teacher has developed with your group during the PFC?	0	1	2	3	4	5	6	7	8	9	10	11
Your teacher was not very orthodox this course, would you go back to work with him?	0	1	2	3	4	5	6	7	8	9	10	11

Thanks for your time and your help. In this way, you can help us to improve the teaching methodology to be applied in future courses. Again, our heartfelt thanks.

Evaluation of the LTP　　Ev PFC-1

Figure 9. Student's opinion about the LTP process in the curriculum.

(2) as **weaknesses** of th is implementation: th e hardness test, the existence of a lot information, a lot of work to be made by the student (specially that one off-class) and the peer to peer coevaluation.

The students themselves suggest some activities to cope for an **improvement planning**, as feedback:

(1) As **improvement actions** th ey propose: to reduce th e quantity of in formation and to apply other forms to ch allenge them.

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(3) As **preventive actions**, they press to give greater freedom and to use specific examples of the syllabus instead of being them themselves to look for them. They are also concerned that this way of working implies great job, in exchange for a far more profitable, but in the long term.

TABLE II. PERFORMANCE MEAN RATES

PERFORMANCE RATE	VALUE
Your opinion bout this teaching methodology	7,2
Understanding of the syllabus competences/objectives	8,1
The development of the group in the "team-work" competence	6,5
The facilitation/supervision/tutoring provided	8,9
Motivation level	7,8
Participation level	9,1
Responsibility level	7,3
Self-sufficiency level	6,2
In general, a mean mark for the whole LTP of the syllabus	7,6

V. CONCLUSIONS

This paper reports an engaging experience based on the methodology and the evaluation in Statistics teaching: students' involvement in building and implementing competence assessment models as a valid learning engagement alternative where the relevance of the assessment criteria is established by the students. The importance of process action research in teaching environments becomes increasingly important to improve the LTP (see Figure 10): students develop a project in groups by applying PBL/EBL techniques where the facilitation tools are essential (see Figure 11). This is one of the main cornstones

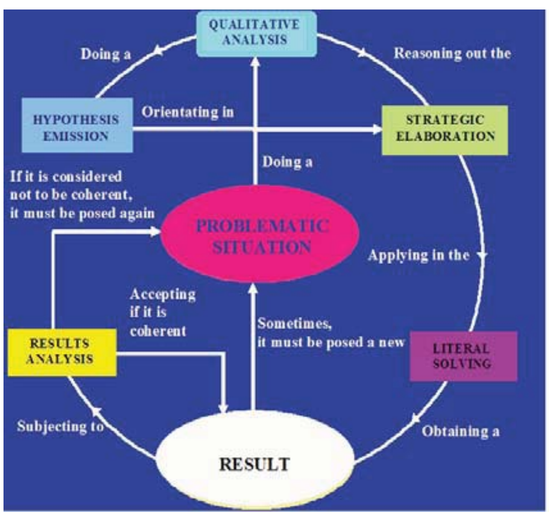

Figure 10. The process oriented research.

The student's opinion is analyzed over a given competence (team work), using such a synergy to promote students' motivation, accountability and participation via challenges. The student has been invited to take part in the design, implementation and discussion of the assessment instrument of that competence through the generation and consideration of valuation matrices. The performance indicators to be considered have been agreed, and a protocol has been established to give students the understanding throughout their formative evaluation process. The competence has been developed in diverse scenarios: the one considered in this paper deals with a Statistics syllabus through course short projects, worked from the perspective of an active learning methodology such as PBL/EBL.

ACTIVITY TO ASSESS		COMPETENCE	APTITUDE FOCUSED	QUESTION TO POSE/ APPROACH COVERED
Looking for the best information in an optimum way	FA	C4	The individualization of the LTP: task assignment	References looked up and constructed used Time used to do the seeking
Definition of the open problem based on the given standards	AA	C4	Student's proactive participation and implication	Rigour and precision of the approach proposed The way in which is declared the future implementation of the Course Project Adequate justification of the choice posed
Role playing in the team/group	FA	C5	Contribution to the cooperative spirit of the team/group	Reasoning about the given role playing proposal in the group How the group worktable has been accomplished? Has the group productivity been followed? How? Which tools have been employed?
Forecasting of the difficulties which could come up/arise	FA	C5	Qualitative analysis of the solution found out	How can be interpreted the resolution of any linear system equation in an approximate manner? Can be a qualitative analysis of the problem made?
Look for values to settle the numeric problem down	FA	C4	Coordination and linking with other subjects of the degree	How the chosen data can be disposed in order to apply the algebraic theory of the syllabus?
Resolution approach and formulation	FA	C5 Ta	sk arrangement	Which methodology type is applied? How the work is distributed among the group members? Is there any concept map about the implementation developed? A Gannt's diagram about times and role playing has been presented?
Result contrast related to the planned outcomes	AA	C4	Coherence between the obtained results and the theory applied	The results looked for have been attained? The values obtained, can be justified?
Analysis of the difficulties that have been encountered	FA	C4 In	teresting contributions	How have been solved the encountered difficulties? How the resources used have been managed? A problematic situation will be suggested (it will be a direct consequence of the project his/her group has worked
Implementation computational costs	FA	C5 Res	ult contrast	How the used method cost has been measured? Is there any cost study?
Teamwork applied methods	AA	C5 S	elf-assessment skills	Quality of the self-assessment report presented Which values are pointed out by his/her group-mates?
Scientific report of the project experience	AA	C4	Helping the use of an appropriate structure for the project approach of the group	How is used the mathematical language and the formal relations? How is it reasoned?
Oral presentation of the report	AA	C5	Coherence of the defence presented	Reasoned justification of the report presentation carried out
Last interview for assessment	FA	C5	Use of the procedural knowledge related to the subject	How does the student answer the questions that have been posed?
Attitude in the facilitation and tutoring times	FA	C4	A more emphatic relationship between undergraduates/students and the teaching staff	Is there a positive attitude in the group structure running? The group, does it appear open-minded, active, productive, efficient, effective, …? A given student, which is the position that shows in the presence of his/her group-mates?

Figure 11. Some questions that are posed to students along the help/tutoring sessions (**FA** means formative assessment; **AA** stands for additive assessment).

A survey has been designed to analyze the student's perceptions regarding the approach, development, assessment and competence analysis from the students' viewpoint. The items considered take into account aspects such as: the information provided, the training involved, the initial level of expectation with respect to the competence, the degree of development reached, the development of the teaching methodology applied, the tutorial action (in the sense of facilitation) applied and the global assessment deployed. The results of this survey are presented in this work to help refocus the teaching methodology with which that competence will be worked in the future.

coached	Step 1	What do we understand about ...? **Clarification of terms** Building a common understanding	class
	Step 2	What are the questions, problems, fields of problem? (Hypothesis?) Which problems have to be tackled first to find a solution? **Definition, Analysis, Weighting of the problems** Naming and organising the problems systematically, extracting the most important	
	Step 3	What do we already know about ...? **Connecting with previous knowledge**	
	Step 4	What knowledge do we miss? **Gap Analysis** Finding knowledge deficits	
	Step 5	**Specifying the learning targets, deriving the work packages and distributing them among students**	
not coached	Step 6	**Carrying out the work packages**	self-study
		Knowledge exchange, Synthesis	class
		Developing a solution, writing the paper	
coached	Step 7	**Discussion of the solution and the its approach with an expert**	class

Figure 12. The PBL approach working concept).

What about student's and teacher's effort? In short, it is different because this implementation is part of a broader strategy to engage students through motivation and participation, while making them see the need to involve themselves in a responsible manner. The subject of the paper lies in the learning engagement domain as student-driven assessment model, taking into account the student's participation/cooperative effort in an assessment set-up as teaching alternative. The results support this work methodology; they highlight the importance of a proper facilitation and supervision to the student progress adequately (see Figure 12) in order to determine the concept structure and the relationships of the involved mathematical units (see Figure 13).

ACKNOWLEDGMENTS

The author thanks the University of the Basque Country for the partial support of this work through the Education Innovation Project UPV/EHU PIE 2008-2010/1.

CODE PDC	TASK TO IMPLEMENT	ACTIVITIES TO DEVELOP	OUTCOME TO MEASURE/OBJECTIVE	ESTIMATED TIME (hours)		DIFFICULTIES ENCOUNTERED
				CLASSROOM	NON-ATTENDANCE	
1	- Presentation of the subject Teaching Planning STP - Explanation of the teaching method that is the base of the Course Project - Text of Course Project as an open problem *This task is reminded from time to time to ensure that students are aware of what it really means*	- Statement of competencies involved in the Course Project - Using simple examples for explanation - Definition of objectives - Influence on the assessment	- Specific questions specific in tutoring/facilitation sessions and/or classroom - Use a daily log as a register diary	0.25		- The student feels that the documentation (delivered on the first day of class) is excessive - The subject guide may be useful to overcome this difficulty, if provided that it is very well designed
2	Finding information in books, magazines, specialised articles, reports, encyclopaedias and /or the Internet, asking to other teachers based on the descriptors of the subject, given the first day of class	The student looked for information on the sources suggested	- The student will deliver the **statement of the problem**, that will work, as openly as possible - **List of** used **references** given by the method of Harvard (examples are given in the STP) - At a later stage, the student will give a complete Problem Resolution (PR) approach, using the modelling suggested when the solution implementation be done	0.	50	- It is normal for the pupil to be disoriented as he is not accustomed to working under the scientific method - Student makes reports handwritten - It is not anything to be delivered as early
3	New reformulation of the search criteria	Very specific descriptors are provided to generate an appropriate search: dynamic system, linear system, linear approach, controllability, robustness, resonant systems, ...		0.17 0.	50	- At this stage any student needs facilitation to be addressed in the right direction - Real-time corrective feedback must be done often, either because students react in a way not intended, either because the expected progress does not materialize in the expected steps/phases
4	New reformulation of the search criteria	The student is told about the most productive topics of the subject		0.	25	
5	Open formulation of the problem, to be solved according to the PR methodology, clearly incorporating the relationships linking the proposal with other subjects of the Degree	The student will have to develop the theory underlying the model presented, linking mathematics and that interest area	- The proposed statement should make clear **the relationship between contents and descriptors** in the subject - **Analysis of the model**: the theory must be described succinctly and directly	2.	00	- The student usually shows difficulties when verbalizing his/her work experience - The difficulties that can lead the future development of the project ought to be written
6	Design of way the implementation of the solution will be addressed	- Problem analysis - Analysis tools that can be used - Locate resources that will be needed	- **List of variables** involved - The student will prepare a **concept map**, organigram or similar, where a **working and calculation strategy** will be provided, reasoning about its key points	0.50 1.	00	- The student does not have a clear idea of the tools to work as a top-down/bottom-up design - The student does not adequately link to the key concepts of the subject with the experience in the Course Project: the concept maps of the thematic units of the course must be continuously be recalled
7	Remember the theoretical concepts involved	Summary of the descriptors most needed to develop the Course Project	**Concept map of the contents covered**	0.17 0.	50	The student must be drawn to study daily
8	Deduction of the working model from the graphical representation	Analyze whether the problem is discrete or continuous, clarifying what the variables are and the relationship between them	- **Deduction of the theoretical model** - **Justified and reasoned statement of the working hypotheses**, to implement the resolution of the problem	0.	50	- Difficulties in discriminating the data and results - The variables are not discussed in the right way - No way are correct Descriptors and keywords are not correctly expressed
9	Refinement of the qualitative analysis	Giving an overview of the whole approach to see if mistakes take place	**Justified listing of the mistakes appearing**	0.	50	The student does devote no time to review and reflect
10	Analysis of the weaknesses of the approach by the teacher	Monitoring, normally permitted, the student		0.50		The facilitation session must be compulsory; otherwise, the student does not come voluntarily
11	Implementation the solution by solving systems of linear equations in the sense of least squares	Calculate the parameters involved in the model of the Course Project	**Coherence of the results obtained**	0.17 1.	50	The student often uses only pencil and paper, not making use of ICT to enhance their overall productivity
12	Deduction of conclusions	Answer in a way justified the questions raised in the Course Project discussion	Results are correct and explanations are well justified	0.	50	There are numbers, no units are provided, and typically the results obtained are not discussed
13	Oral presentation and/or written report for the Course Project	Perform a PowerPoint presentation that summarizes all the essentials of Course Project outcomes	**Quality of the report/presentation** following the criteria reported in the valuation rubrics at the beginning of the course	1.	00	- There is not too much interest to generate a document with enough presence to the university level - There is no autonomy when generating the report of the Course Project
14	Evolution of the student's evolution and progress in mastering the techniques involved in the Course Project	Interview (3 sessions of 10 minutes) with the teacher of the course on an individual basis and with other group members	Daily records	0.50		It is quite difficult to verbalize feelings and emotions in front of a teacher, and more if other students are there, albeit in a small group
15	Final evaluation of the work done with the Course Project	Personal interview Team interview Analysis of team data and student's data	Summative assessment of the Course Project with the student's follow-up, and the opinion of each group member	0.25		Initially, the student is reluctant to assess their colleagues, provided that there is no group mentality
16	Following the REDER philosophy the learning-teaching process of the Course Project is reviewed on an ongoing basis, which has the corresponding control mechanisms	Quality of the Course Project report Oral presentation of the Course Project Student's self-evaluation	Lejk's method to **evaluate the team guided work**, that has done the Course Project			Students need to comment the assessment results to them as immediate or mediate feedback

Figure 13. Flow diagram of the Course Project implementation (formative and additive assessment in blue colour).

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VALUATION MATRIX / RUBRIC: TEAMWORK 1/2

		COMPETENT (5 MARKS) *It has been fully met*	ACCEPTABLE (3 MARKS) *Some mistakes are evident*	DOES NOT MEET (0 MARKS) *It must be again redone*	Q
General level of the team/group	*Organization and presentation*	The report is bound and formatted: there is an index, it is well structured, indexed and paged, there are references and appendices. The important thing is the main area, the accessory is led to the annexes. The construction, syntax and spelling of the sentences is correct. The explanations are clear. The title of the report is very suitable	The memory is not well structured, but contains all the required sections. Lack of clarity in the explanations provided. There are spelling errors. Much explanation is not given. The title of the report is adequate	The report is not formatted, there is no index, poorly structured and is not paged, no reference. Misspellings abound. It is not clear. No resources are used well. The title is not suggestive	
	Contents development	It makes use of all contents and descriptions of the subject, relating them adequately	These findings indicate that some content does not appear, or the explanations are limited	The contents presented are inadequate. There are only relations	
	Argumentation and justification	The results and accompanying comments are justified, using the theoretical concepts and practical convenient descriptors	There are results and / or comments that are not justified or not based on the concepts and theoretical and practical descriptors	No reasoning is provided	
	Coherence	There is consistency between what the group has worked and the presentation conducted. It is noted that there has been a cooperative work. All the deadlines have been respected	Not all the members have managed to cover the understanding of the entire project. The group's work has been collaborative. Sometimes times have not been observed	Each member is responsible only for their share. The work has been individualistic, or only one component has worked	
	Objectives of the Course Project	The report submitted meets the all the requirements of a project	The report submitted meets the some of the requirements of a project	The documentation submitted does not represent at all a research report	
Procedures in preparing the project report	*Class attendance*	There was a total attendance of all members at every meeting	Any member has not attended any meeting. Few meetings held	There has been little meetings. It has produced an individualistic work	
	Compliance with rules	The group has met the standards that have been established. The workflow has been dynamic	The group has worked in a dynamic but in a somewhat anarchic	Rules have not been respected	
	Selecting the item submitted	The group's mission is very much in line with the selection of the work submitted. And it has a large component of elements of the subject with proper justification	The group's mission is in line with the work presented. Yet covering most elements of the subject, are well justified	The issue presented was to get by	
	Resource planning	There has been adequate foresight and planning of resources and time, and carried out according to the objectives set	Resource planning has existed, but were not always met expectations	There is no planning activity	
	Group consciousness	Group members were informed of the progress of others. There has been rotating roles. The methodology was designed in accordance with the objectives designed. Were achieved initial results expected	Group members were informed of the progress of others. There has been rotating roles. The initial results have not been reached	The group has been a complete chaos	
	Effective meetings	There have been all calls, records and evaluations of all sessions. The group's work plan has been presented and justified	There have been some calls, some records and / or evaluations of the sessions. The group's work plan has been presented and justified	No calls, no records, no evaluations of the sessions. There has been no work plan	

VALUATION MATRIX / RUBRIC: TEAMWORK 2/2

		COMPETENTE (2 PUNTOS) *Se ha alcanzado completamente*	ACEPTABLE (1 PUNTO) *Se aprecian algunos fallos*	NO CUMPLE (0 PUNTOS) *Se ha de realizar de nuevo*	PUNTOS (1)
Relationships in the group	***Work cycle in the group***	Group consciousness has been developing the qualities of the group beyond a PDCA cycle (plan-do-check-act). The cooperation has been evident. Resources have been shared	The group has worked as a PDCA cycle. It has always cooperated. Resources have been shared	It has not been reached a PDCA methodology. The cooperation has been conspicuous by their absence. There are no shared resources	
	Communication in the group	Communication within the group has been completed in the records, and is reflected the evaluation report of the group. No member of the group has given any objections over the project development	Communication within the group has failed at times, but it is also unclear in the report submitted	People have not behaved as a group	
	Leadership	There has been a person that stands out above all others. It is equally valued the contribution of the group members	It was necessary that a person in the group moved to the other so that the work was carried to fruition. Sometimes, the contributions made have not been equally valued	A person has clearly dominated over other people in the group. The other members were subject to the decisions of that person	
	Autonomy	The teacher only replied to questions made by the group	Special sessions have been required with teachers for the project to move forward	The group has completely disengaged from the process of tutoring, ...	
Emotion treatment	***Integrating the differences***	Nobody has outperformed all others, trying to involve colleagues, when necessary. It has fostered healthy disagreement and debate, working consensus. Constructive criticism has carried out	There have been problems that are resolved in a process of communication within the group. There has been disagreement and debate in a healthy manner. Sometimes, they have not produced well tolerated criticism	The friction between people have been constant. Not rated opinion of the members. The disagreement has been constant.	
	Conflict resolution	There have been no conflict because team members were very clear that what mattered was the person to achieve the objectives of the group	There have been conflicts, because no team members were very clear that what mattered was the person to achieve the objectives of the group. It was necessary to apply decision-making techniques to make some decisions	Conflicts have been continuous	
	Recognising the individuals	When it has been necessary the merit of individuals has praised. There are recorded in the reports of the group. This fact has been made public in the usual dynamic class	Only the teacher has stressed this fact in front of the class (as large group)	There have been no such indications	
Evaluation	***Transmission of knowledge***	The group has shown that there has been learning from each other	The group has not demonstrated that there was learning from one another	The group has not demonstrated that some members have helped others	
	Obtained outcomes	The objectives achieved are in line with the initial objectives. The reasoning is well structured	There have not provided all the original aims. There are errors in the reasoning	The results achieved are far from the objectives. There is no reasoning	
	Evaluation modes	The group has carried out formative and summative assessment. In addition, its members have been involved in evaluating	The group has not performed work for formative or summative evaluation. In addition, its members have not fully involved in the evaluation	They have not been involved in evaluating	
	Self-evaluation report	The group has performed a very detailed report, and all its members have participated	The evaluation report is vitiated by the no participation of its members	There has been no self-evaluation report	

Figure 14. An analytic rubric for assessing the team work competence.

Analyzing self-reflection by Computer Science students to identify bad study habits

Self-reflection performed by students of programming courses on the study habits and skills acquired through b-learning supported by an automatic judge

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***Abstract* — We present some preliminary results and the main conclusions of a study that we conducted at the University of Algarve, for one of the programming courses in the first year of the Computer Science degree at the University of Algarve. We analyzed the self-reflections made by the students about their study habits and about the skills they acquired in the course. This particular course uses a methodology of blended-learning supported by an automatic judge. The research data were obtained through questionnaires that were distributed and collected during the period of study between the end of classes and the exam. We took into account data from other instruments related to previous work carried out by students, in this course and in previous courses, as well as the performance of the students. We intended to ascertain to what extent the planning, motivation, previous study or knowledge about the type of examination influenced final results. The results suggest measures to be implemented in future editions of the course.**

Keywords – Blended-learning, automatic judge, self-reflections, study habits and acquired skills of programming students, learning constrains.

I. Introduction

In general, the student population enrolling in the Computer Science Programme (CSP) of the University of Algarve (UAlg) is mostly composed by young adults (with 18 or 19 years of age). These students carry to the university the knowledge, skills, attitudes, study habits, motivations, interests and expectations that they acquired in secondary education and from other cultural experiences. They also bring the weaknesses referred in [1], that we must not ignore. In any case, those motivations, interests, and expectations do not always have the expected effect in helping them achieve academic success within the prescribed time. Furthermore, we have observed that accumulated failures as a result of difficulties in developing the skills for writing computer programs that require more than superficial knowledge cause students to stay at the university as adults (say, with more than 24 years of age).

We believe that it is the teacher's responsibility to encourage students in building a deep, responsible and autonomous knowledge for the adoption of rich, diverse, motivating and demanding strategies from a cognitive point of view [2], which aim the gradual and progressive application of andragogy [1] principles (adult education), and not only of pedagogical principles, and to identify factors that can condition the development of the competences necessary for programming. Accordingly, in the academic part of the course Algorithm and Data Structures (ADS) we have been following a blended-learning approach, based on the availability of tools that support the learning process and the evaluation of results, as well as an automatic judge that automatically evaluates the programs written by students [1], thereby releasing teachers to more gratifying pedagogical tasks. Since ADS is the second course in programming in the study plan for Computer Science, students were supposed to master the basic competences that were the subject of the first course, and be able to apply them and learn new ones, such as the following: writing C programs which require the use of libraries of data structures, selecting the best data structures and the best algorithms for the task at hand, and being able to participate in programming contests, by showing that they can solve the problems that typically are presented at such contests. However, Computer Science teachers recognize the students' difficulties on acquiring these competences, and try to help them identifying their fragilities, the cause of these fragilities, and ways to overcome them. In order to fully appreciate the students' difficulties, we targeted this study to identify the cognitive competences required for reaching success in the course, that is, to obtain results that lead to a score above minimum grade.

A. *Cognitive competences of programming*

Studies based on characterizing cognitive competences of university students often refer to Bloom's six-levels taxonomy: knowledge, understanding, application, analysis, synthesis and evaluation [3]. Those studies indicate that students, in general, initiate their learning by a superficial approach, which corresponds to the first three levels, and then evolve in a gradual and progressive way to a deeper approach, which corresponds the last three levels. A more recent version of this

[1] According to Waal and Telles there are five andragogy principles: autonomy, experience, learning interest, learning use and motivation to learning.

taxonomy [4] differs from the original one on the terms used to name competences. There are now referred to by a verb, thus reinforcing the mind activity at each level: know, understand, apply, analyze, evaluate and create. The most meaningful modification is at the two top levels. As shown on the following picture "synthesis" is replaced by "create", a new competence, placed at the top level.

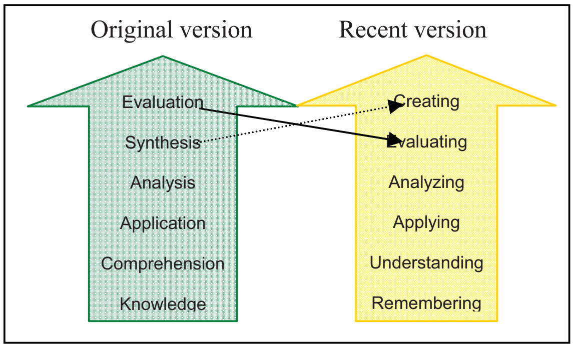

Figure 1. Changes on Bloom's taxonomy

Despite all the technical innovations that come with it, we believe that programming is still mostly a creative activity, encompassing analysis and synthesis [5], requiring a critical assessment, including self-assessment, and generating discussions with peers, centred on the resolution problems through programs and involving an important component of decision-making. All this must be supported by deep reflection and understanding of the basic principles, capable of backing up the decision that has to be made, sooner or later, in selecting the most effective programming solution for the given problem.

For the present work, we relied on Bloom's original taxonomy, which seemed more convenient to describe the natural path of an interested, motivated and hardworking college student, dedicated to learning the basic principles and good practices of programming. The student, when confronted with a hierarchy of skills he has to master, and consequent assessment he will have to go through, will certainly first familiarize himself with lower level competences, which in the case of programming means to know and understand syntactic and semantic rules of language and how to apply them to solve simple programming problems. Usually the exercises presented here should be helpful to:

- Diagnose weaknesses in students, concerning their background knowledge;
- Evaluate the degree of student difficulties in simple programming tasks;
- Elucidate and train students, preferably through effective teaching strategies, that provide them sequential action guides (say, "storylines" with step by step tasks) with the information and clues for gradual and progressive development of higher-level programming skills.

For the application of top level competences, the student should be led to solve challenging problems, which involve interpreting the problem statement, with acuity and attention, keeping in mind the principle of " divide and conquer". This means to decompose the problem into parts, as independent as possible of each other, and analyze their relationships. Assembling the parts, whose reciprocal relations must have been identified, with the aim of reaching the solution of the original problem, is the synthesis competence. Creativity in programming will reside in these two skills. Usually, it is by practicing with self-assessment on the tasks performed and with judging the value and merit of the material they created, that students improve their critical sense and their ability to take the right decisions. This seems to be the natural attitude human beings take in learning and problem solving, either everyday's problems or programming problems. But if this is the natural course of learning, why is it so difficult for the majority of students to acquire the highest level competences in programming [6, 7]? In order to find an answer to this question, we examined the difficulties and considered strategies for developing those competences in students.

1) Impeditive factors to acquire high level competences

For this issue, we considered the impeditive factors for the development of the critical and creative competences necessary to reach full success, on ADS course. We identified the following characteristics for those programming students with low capacity progression on those competences:

1. Lack of effort and persistence to apply the knowledge acquired, as a result of a lack of taste for mathematics or by a low motivation to fulfil these tasks, in this case as a consequence of the perception of difficulties or assumed individual incapacity, or even caused by competing personal interests;
2. Satisfaction on the fulfilment of the minimum requirement for the approval, for the reasons stated on the previous point;
3. Adoption of basic techniques that have been learned in the past, in other contexts, and refusal to try out new, more sophisticated methods, that, nevertheless are more effective and respect more the basic principles and good practices of programming;
4. Limits at the level of abstraction and logical thinking, of mathematical knowledge or other underlying concepts and techniques underpinning the programming problems presented;
5. Weaknesses on planning the workload, and coordinating the various tasks, a competence more important with the widespread adoption of the Bologna model;
6. Concerns caused by the amount of effort necessary to develop all the stated competences.

2) Possibilities to stimulate the development of high level competences

In an attempt to find solutions to some of these problems, we headed for a first analysis of a classic article [8], often quoted in educational circles, where Dijkstra argues that learning is a slow and gradual transformation of "new to usual", reinforcing the idea that learning programming is what he calls the "great news". Jenkins, in [6], supports the argument of Dijkstra and adds that the programming is a subject that is difficult to master, but that it should not be impossible to overcome this obstacle. Other studies promote deep learning [9, 10]. In particular, the study [9] tries to demonstrate that the strategy "peer review" promotes deep learning in programming courses. The author argues from experience that when students evaluate the work of their colleagues they think deeply, see as others solve the problems, learn to criticize constructively, thus improving the capabilities of critical thinking. The author also refers other strategies to force deep learning, stressing the importance of the implementation of reflective learning in higher education based on the application of knowledge to new situations or in different contexts.

The present work is inserted on a research line whose goal is to evaluate the efforts on the application of b-learning supported by an automatic judge [1] that automatically evaluates the programs written by students, as strategy to promote deep learning, in Computer Science students.

In this article we report the case of the ADS course, analyzing self-reflection exercise made by students in the post-examination period of the academic year 2008-2009, their study and learning habits through b-learning supported by an automatic evaluation tool, during the period of preparation for the exam, which roughly corresponded to a week between the end of classes and the day of the exam. We attempted to identify core competencies in planning the study, effort and action in accordance with the planning and execution of the exam, as factors to develop or maintain in future editions of the subject. The research data were obtained through questionnaires collected from a sample of students who attended the examination. We took into account data from another sample of students on a preliminary study conducted during the period of classes. This study was more concerned with the gradual acquisition of key programming skills by the students, and balanced out the limitations in the study that was carried out in the period of preparation for the exam. We also factored in the results of the students both in the labs (during the period of classes) and in the exam. The questionnaires were implemented as surveys, available through the webpage of the course, at the Moodle learning management system. Both surveys were designed in Google Docs [11] [12]: the first at the end of the subject course work, on the preliminary study; and the second after the examination, on self-reflection after examination. The data were treated in terms of characterizing the profile of the group of students in the course and also the individual profiles, in order to confront the results of each student with the results of the group, and also for comparing the competences that were acquired by each with the key competences that had been identified.

The goal of this research is to instil in upcoming students an awareness of the most common weaknesses, or critical points, to the development of high level competences. Equipped with these findings, the teacher will have a concrete mean to advise or help students in acquiring key competences, which will allow them to leapfrog the learning progresses. Next, we present our case study.

II. STUDY CASE

A. Preliminary study

For the analysis to the preliminary study, were considered 23 questionnaires, gathered at the end of the five weeks of classes, for the ADS course and before the period of preparation for the examination. We expected a larger number of responses, since 136 students enrolled and 56 actually attended classes. We had 17 (74%) male students, 15 (65%) full-time students, and the rest with some kind of part-time occupation (but less than 8 hours/day), 14 (60%) with ages between 18 and 24 and the rest with ages greater than 24 years. We recorded only 4 (17%) respondents that enrolled in this course for the first time, 7 (30%) that enrolled for the second time and 12 (53%) that were enrolled for the third time or more. Apparently, many students who quit on the first week of classes (and did not make it to the exam) have shown signs of lack of preparation and courage to attend this programming course. There was a clear trend of withdrawal from this course by the younger students enrolling for the first time, balanced by a large participation of former dropouts, who continue to enrol year after year, some having already reached an adult age[2]. The most common justifications for the previous failures were: a) lack of basis on mathematics, or other basic subjects, by 12 (52%) respondents; b) the short five-week compact term adopted experimentally by our university, by 11 (48%); c) lack of motivation, little effort and persistence on learning, by 10 (43%); d) high levels of uncertainty specially near the exams, by 7 (30%). So we have identified a group of respondents that are aware of their past weaknesses in programming, but that have shown signs of: a) willingness and persistence to succeed, on the opinion of 13 (54%); b) frustration and anxiety on the opinion of 11 (46%); and c) a tendency to drag the course and postpone success, on the opinion of 9 (38%). The responses do not allow us to conclude that repeated failures are an immediate motive for academic abandonment, with the exception of 5 (21%) that have shown some signs in that direction. We observed that 16 (70%) respondents stated that they enjoy programming, but 13 (57%) did not liked mathematic and, curiously, only 7 (30%) were motivated by both programming and mathematics. We also detected 3 (13%) dramatic cases of students who like neither programming nor mathematics. These are disturbing results, but they match those from [1]. We then analyzed the degree of satisfaction in relation with activities preformed as part of the course, in relation to the usage of Moodle platform, of the automatic evaluation tool, Mooshak[3], and also in relation to the competences acquired, personal interests, programming skills, expectations for the ADS course, and their relation with the results obtained in the mid-exam (an average of 12.4 values), before the final exam.

1) B-learning supported by an automatic evaluation tool

B-Learning, supported by the automatic judge Mooshak, was the learning strategy adopted for the ADS course, to support on-class learning, on the one hand, and to induce autonomous work, on the other hand. The information on course goals, learning outcomes, assessment methods, and types of work required were presented form the beginning. The lectures were recorded on video and made freely available on the Moodle platform, in order to reinforce learning and

[2] Therefore one of the competences to improve, on future editions of the subject, will be to avoid the postponement of success.

[3] *Open-source* automatic judge applicable to programs with text entrances and exits, developed by José Paulo Leal, from Porto University.

stimulate autonomous work at the rhythm of every student. So-called "continuous evaluation" was performed by: 4 "storylines" in total, with a detailed description of the tasks to be performed, matching the decomposition of the given problem in sub-problems, with instructions or suggestions on how to write programs for them and also on how to test the sub-problems and then how to weave the programs for the sub-problems in to the full program, this way paving the way towards the gradual and progressive acquisition of high level competences; 3 problems of the style used in programming competitions to apply those competences; and self-evaluation quizzes, after each lecture, to consolidate the subjects taught in the lecture. In this case, 3 (13%) respondents tried to make all the quizzes, 8 (35%) considered them useful, 1 (4%) fun and 7 (30%) have agreed that they helped remembering the issues discussed during the lecture, while 3 (13%) considered some questions took too much time to answer. All programming tasks were evaluated with automatic return, either through Mooshak[4], and either by the Moodle platform. There were also written reports on the "storylines", submitted through platform. These reports were read by the teachers, and scored by hand. Remarks were sent to each student by the teacher, again using the platform. We observed that 14 students (61%) agreed with the evaluation system used in the course, while and 7 students (30%) had some concerns and hesitation about the rules. On the issue of the interaction between teachers and students, 16 students (69%) agreed that the communication through the platform was effective and 12 students (52%) considered that the teacher's face-to-face feedback should be emphasized, again a situation similar to the one of reported in [1]. However, there were 8 students (35%) who stated the course required too much work, and 7 students (30%) revealed uneasiness on time management. Likewise, 16 students (69%) agreed that learning activities took more time than expected. Some respondents said to have acquired, through the use of Mooshak and the Moodle platform, essential study competences, such as: a) more careful on planning activities and meeting deadlines, with 15 (65%) agreements and 5 (21%) hesitations; b) more rigor on the activities fulfilled and submitted, expressed by 15 (65%) agreements and 6 (26%) hesitations; c) more motivated to fulfil the activities, with 16 (70 %) agreements and 3 (13%) hesitations; d) 14 (61%) have felt some learning progresses and 6 (26 %) hesitated; e) 16 (70%) developed critical spirit, creativity and problem resolution capacity and 6 (26%) hesitated, f) 12 (52%) have recognized that the evaluation system was fair and transparent and 6 (26%) hesitated; g) 10 (43%) agreed that the variety of exercises have measured their knowledge and competences, with 9 (39%) hesitations; and h) 11 (48%) said to have improved their academic performance, despite the 8 (35%) hesitations.

Based on the calculus of the average ranking (AR), through the weighted average of the four items rated using a Likert[5] scale, presented in the previous table, it was showed quite favourable behaviours (with values above 3) on the respondents' attitudes in relation to the study:

TABLE I. AVERAGE RANKING OBTAINED IN THE PREDISPOSITION IN RELATION TO THE STUDY

Aptitudes in relation to previous study	AR	Comportment
1. *I actually face the study* with seriousness and as an obligation to satisfy my interests	4,1	Favourable (with 17% of uncertain)
2. Usually I fulfil the terms of my study plans, even if arising calls for fun.	4,0	Favourable (with 17% of uncertain)
3. When I can't fulfil the obligations (delivering of works...) I'm frustrated.	4,1	Favourable (with 17% of uncertain)
4. *Not passing on* is something that bothers me a lot.	4,3	Favourable (with 13% of uncertain)

In this case, 19 students (83%) stated, some (10) with more conviction than others (9), that faced study with seriousness and as an obligation to satisfy their interests, 4 (17%) have revealed hesitations and 1 (4%) depreciated the study. Furthermore, 18 students (78%) said they pursued personal fulfilment and 19 students (82%) wanted autonomy and independence from the family. In this case, only 1 student (4%) showed signs of hedonism (4%), 3 students (13%) showed signs of indifference towards the study, and 1 student (4%) wanted with desire to exert authority, influence and enhance public image. Yet, despite the visibly favourable results, study commitment beyond favourable predisposition requires task planning, effort and actions in accordance with the plan, even if in programming, the capacity for action is, in most cases, a direct consequence of the students' abilities. Accordingly, we sought to analyze the abilities acquired in programming, through the following table:

TABLE II. AVERAGE RANKING OBTAINED ON PROGRAMMING ABILITIES

Abilities in programming	AR	Comportment
1. I'm able to solve the most trivial problems of the subject.	3,6	Favourable (with 26% of uncertain)
2. I know and understand the rules of the C language and I apply them in the most trivial exercise.	3,5	Favourable (with 17% of uncertain)
3. I acquired skills for problem solving typical programming contests.	3,4	Favourable (with30% of uncertain)
4. I'm able to analyze challenging problems, its decomposition, relationships, joint parties with the aim of reaching the solution.	3,3	Favourable (with 39% of uncertain)
5. My logical or mathematical reasoning has been effective in most evaluation work.	3,5	Favourable (with 30% of uncertain)
6. I acquired skills to decide on the best programming solution to a unique problem.	3,3	Favourable (with 35% of uncertain)
7. I rarely commit lapses in programming.	2,1	Unfavourable (with 30% of uncertain)

The table presents an analysis of data provided by respondents in relation to their ability to programming. The existence of positive behaviours can be inferred, although these are not as massive as those found in table I, as shown by AR variables and the high rates of response with hesitation. It

[4] After the submission of each task, this automatic judge returned one of the feedbacks: Accepted, Presentation Error, Runtime Error, Compile Time Error, Time Limit Exceeded, Memory Limit Exceeded, Wrong Answer or Invalid Function.

[5] The scale was scored in a way that 0 was "don't know how to answer", 1 to "strongly disagree" and successively until 5 for "strongly agree". A value lower than 3 for each item corresponds to a favorable comportment of the students; a value below 3 to an unfavorable comportment caused by some contrariety; and value 3 corresponds to an uncertainty comportment, that can be a sign of fragility or indifference.

should be noted that the uncertainty has increased and the AR decreased with the increase complexity of the exercises and of the workload in general. The results point to greater difficulties in acquiring high-level skills, visible in sections 3, 4, 5 and 6 of Table II, that are fundamental to the full success in the subject. The last variable implies unfavourable behaviours, despite the uncertainty of 30 %, where it appears that most respondents admitted committing errors on programming caused by lack of attention to detail, or so they think.

We then analyzed the expectations of the students in relation to the final results in the subject, after the examination. In this respect, we found that 13 students (57%) were not very ambitious, and would be happy if they achieved the minimum score for approval, 5 students (22%) were undecided and the remaining 5 students (22%) expressed dissatisfaction in getting minimum levels. In this case, the respondents were trying to be modest when expressing they would be satisfied if they could reach the minimum requirements for approval [6], possibly because of the too many failures in past editions of the course, and also because they are aware of the weaknesses of their programming skills.

B. Self-reflection of students after the ADS examination

After the ADS exam we collected data from 10 questionnaires, from a set of 28 possible respondents who attended the exam. Thirty seven students took the exam, with relatively good performances in the evaluation carried out during the period of classes. Indeed the average for those students that came to the exam was 12.4 points, for a maximum of 20 points. The average score in the exam was 8.0 points. There were 12 that passed, 6 of them with grades above or equal to 12 points (12, 13, 13, 15, 15, 18) and the remaining 6 with a grade between 10 and 11 values (10, 11, 11, 11, 11, 11). Of the remaining, 16 students failed and 9 were absent. These results are very disturbing and more so because of their persistency over the years. It is difficult to find an explanation other than poor study habits of students.

Therefore, it is interesting for the students to do an exercise of self-reflection, after the exam, concerning their study habits, and compare the results with those of the preliminary study. We can also relate the results to the effort and actions conducted in preparation for examination, the examination itself, and if the effort was worth it and the perception of whether the preparation effort was worth it. The data indicated that on the exam 9 respondents were male, 6 were young adults and 4 were adults over 24 years of age.

1) Planning carried out during the pre-preparatory study

The planning of the study is a key skill for any student. Essentially, it consists of a reflection on the preparation, visualization and design of the tasks to be performed. At this point it was noted the following questions had at least 50% of expression of interest: Qpl_1) hot trends, that were likely to be at the exam; Qpl_2) questions frequently asked by the teacher during the lectures; Qpl_3) more profitable time of day; Qpl_4) the favourite place to study, Qpl_6) ways to avoid distracting factors, Qpl_7) definition of learning goals, materials or technology necessary; On the downside questions Qpl_5) profitable study hours and Qpl_8) the distribution of study and rest times and what strategies to use to avoid anxiety states obtained 40% of records. In the respondents reflections after having seen the exam was verified that only 20% of them, corresponding to R1 and R2 of the following table, defended the way they prepared themselves, since considering to have obtained a good result, even if R2 admitted a final result below his expectations. The key issues envisaged by all respondents, and advised to be improved by some or maintained by others, are in the following table:

TABLE III. QUESTIONS PONDERED ON STUDY PLANNING

	Qpl_1)	Qpl_2)	Qpl_3)	Qpl_4)	Qpl_5)	Qpl_6)	Qpl_7)	Qpl_8)
Respondents	R1	R1	R1	-	-	R1	R1	-
	R2	-	R2	R2	R2	R2	-	-
	R3	-	R3	R3	-	R3	R3	-
	-	-	R4	R4	-	-	-	R4
	R5	R5	-	-	-	-	R5	R5
	R6	R6	R6	R6	R6	R6	-	-
	-	-	-	-	-	-	R7	R7
	R8	R8	-	R8	R8	R8		R4
	R9	R9	-	-	R9	-	-	-
	R10	-	-	-	-	-	R10	-

2) Action and effort in preparing for the exam

The effectiveness of the preparation for the exam will be greater if the planning is good and if the subject studied during the classes have been consolidated.

Usually this period of preparation for the exam is used to review the course, overcome the perceived remaining difficulties, solve again tests, exercises and problems that have been done, invent of new exercises, etc. At the end of the study, and before the exam, it is important to make a self-assessment of learning, so that the students themselves feel responsible for their study habits and results they will obtain. In the case we analyzed, all respondents used the preparation time to study, as shown in the following table, and the study was always or almost always conducted with the support of materials and technology available on the platform:

TABLE IV. TIME DEDICATED TO STUDY WHILE PREPARING FOR THE EXAM

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
Days / Hours of study in a week	3/40	4/80	2/14	5/15	5/45	3/12	3/12	3/42	3/15	2/10
Hours devoted to the study were profitable	fully agree	agree	agree	neither agree nor disagree	agree	neither agree nor disagree	agree	agree	neither agree nor disagree	agree

The data confirmed that respondent R1 was the one who was confident that the hours dedicated to study were profitable. On the other hand, we observed that in relation to the questions presented here: Qac_1) all respondents reviewed the theoretical materials; Qac_2) 70% analyzed previous exams used in past editions of the course; Qac_3) 50% solved again the exercises presented during the course; Qac_4) only 10% invented new exercises from the ones made available on the platform, the

[6] To avoid satisfaction in obtaining minimum grade on the subject is other competence to be developed in future editions.

remaining 50% despite agreeing to the effectiveness of their study strategy did not show it clearly and there were 40% of hesitation; Qac_5) no respondent claimed to have solved the proposed exercises for which a solution was not available for reference; Qac_6) 50% revealed, but without much conviction, to have made self-assessment of their learning, 10% hesitated and the remaining 40% stated they did not; Qac_7) 30% of respondents said that throughout the study were able to formulate their own questions and that therefore there was no reason for being anxious before and during the exam, 30% hesitate and 40% disagreed; Qac_8) interestingly, 80% of respondents studied alone; Qac_9) for doubts that arose, 40% relied on colleagues (in person or in forums), 30% referred to other means and no one tried to reach the teachers during this period. It is important to notice that 40% of respondents indicated that the effort in the preparation paid off for having gotten a better mark than the one they would have got if they had not prepared themselves. The effort and actions conducted by these respondents is showed in the next table:

TABLE V. ACTION AND EFFORT WHILE STUDYING FOR THE EXAM

Qac_1	*Qac_2)*	*Qac_3)*	*Qac_4)*	*Qac_5)*	*Qac_6)*	*Qac_7)*	*Qac_8)*	*Qac_9)*
R1	R1	-	-	-	R1	R1	R1	-
R3	R3	R3	-	-	-	-	R3	-
R6	R6	-	-	-	R6	-	R6	R6
R7	R7	R7	R7	-	R7	R7	R7	-

By analyzing the Table V, the respondent R7 distinguished himself from the others for, besides all the effort and action in the preparation for the exam, having been the only one to reaffirm that he tried to imagine new exercises from the ones available at the platform and for presenting himself as the more convinced that his study strategy was effective to relax and avoid anxiety. It was found that, like R7, R1 also maintained a positive spirit during study and examination. These two students have thus shown skills of self-motivation and the capacity to formulate their own questions in situations where normally in order to find the answers one must have a thorough knowledge of the subject. Respondents R1, R6 and R7 also performed the self-assessment of their learning, thus taking self-responsibility for their actions in the study. However 40% of the respondents felt that the effort of preparation was not worth it because they obtained a mark below their expectations. The effort and actions conducted by these respondents are given below:

TABLE VI. ACTION AND EFFORT WHILE STUDYING FOR THE EXAM

Qac_1	*Qac_2)*	*Qac_3)*	*Qac_4)*	*Qac_5)*	*Qac_6)*	*Qac_7)*	*Qac_8)*	*Qac_9)*
R2	R2	-	-	-	-	-	-	-
R5	R5	R5	-	-	R5	-	R5	R5
R6	R6	-	-	-	R6	-	R6	R6
R8	-	R8	-	-	-	-	-	R8

In this case, no respondent stood up with enough self-motivation to formulate their own questions, although Table IV shows that these were the ones who have dedicated more time to study during preparation time. We observe that respondent R5 also took personal responsibility for his actions. It is worth noting that R6 respondent considered that this effort allowed him to get a better grade than he would have got if he did not make some effort. Still, he was not happy, because the grade below his expectations.

3) Making the ADS exam

During the exam, we observed that the study strategies used specially by R1 and R7 worked as a key competence to grant success at the course. Next, we present a graphical summary of the main difficulties felt by this group of respondents during the exam:

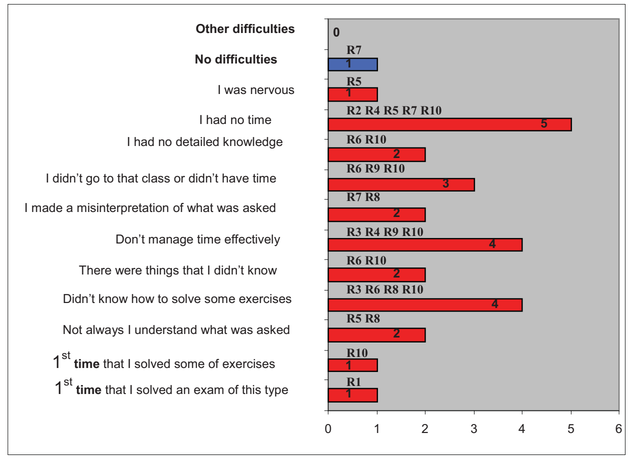

Figure 2. Difficulties on the ADS exam

R7 was the only to affirm not to have felt any difficulties, while R10 was the one who felt them the most; R5 assumed some anxiety. The most limitative fact or for this group of students was time. Thus, this must be one of the key competences to be improved on future editions. Like on other areas of study, for exams in programming courses, it is always necessary a deep acquaintance with the subject, so that the right answers come to mind faster, with the self-confidence and self-control. These are fundamental aspects that help to dissolve the fragilities of time management, anxiety, etc.

The exam was structured into five groups, as follows: the first group is a quiz similar to the ones used for self-evaluation questionnaires after each lecture; the second group with a simple question about the output generated by a "mysterious" function that implements in disguise one of the algorithms studied in the course; the third and fourth groups have questions that apply the knowledge acquired in the context of a new set of functions; the fifth group is a problem requiring a complete program, like the tasks submitted to Mooshak, typical of programming contests, using some data structures and some algorithms that the students must have learned during the course. Accordingly, we analyzed the key competences to maintain or improve on the resolution of the first, second, third and fifth groups of the exam (given that the fourth is equivalent to the third):

TABLE VII. STRONG AND CRITICAL POINTS IN THE RESOLUTION OF THE THREE FIRST GROUPS OF THE EXAM

Key competencies to maintain (bold) or to enhance (normal)	**1st Group**	**2nd Group**	**3rd Group**
Many difficulties	R6	-	R8, R10
Withdrawal at first attempt	-	-	-
First time I do these exercises	R1	-	-

I kept calm and was careful	**R1, R3, R4, R6, R8, R9, R10**	**R1, R4, R6, R7, R8, R10**	**R4, R6, R10**
For not to make mistakes I preferred not to respond	R6, R10	-	-
Not studied in detail	R6, R10	R10	R4, R8, R10
I memorized this matter	-	-	-
I recognized the matter and was able to apply it in context of these exercises	**R1, R3, R4, R5, R6, R7, R8**	**R2, R3, R5, R6, R7, R9**	**R1, R2, R3, R6, R7, R9**
I had no detailed knowledge that would allow me to respond well	R2, R6	R10	R5

On the execution of the first group (the quiz), we draw attention to respondents R3, R4 and R8 who revealed more key competences. On the next level we have R1, R5 and R7. On the other hand, R6 was the one who presented more weaknesses on the quiz, followed by R2 and R10. On the two following groups, to implement functions, the emphasis goes to R6 and R7, with key competences to maintain, followed by R2, R3, R9 and R1. On these exercises, R10 was the one with more difficulties, followed by R8, R4 and R5.

TABLE VIII. STRONG AND CRITICAL POINTS, ON A RESOLUTION OF A PROBLEM TO APPLY HIGH LEVEL COMPETENCES

Key competencies to maintain (bold) or to enhance (normal)	5th Group
Many difficulties	R9, R10
First time I do these exercises	R10
Withdrawal at first attempt	R10
I kept calm and was careful	**R1**
For not to make mistakes I preferred not to respond	R10
Not studied in detail	R7, R10
I recognized the matter and was able to apply it in context of this problem	**R1, R2, R7**
I had no detailed knowledge that would allow me to respond well	R3, R6, R8, R10
I should have studied the matter thoroughly to respond quickly	R3, R10
I correctly interpreted the statement of the problem	**R1, R4, R6**
I identified the data to solve the problem	**R1, R2, R5, R6, R7, R8, R10**
I was able to build a mental algorithm to solve the problem	**R1, R6, R8**
I decomposed the problem into parts independent of each other	**R1, R2, R3, R6, R7**
I analyzed the relationships of the parties, which could resolve	**R1**
I joined the parties well linked, with the aim of reaching the solution of the problem	**R1, R7**
I'm aware that I presented the most efficient solution that it is possible	**-**
I had difficulty in applying the knowledge in the context of the problem	R5
I had difficulties in my reasoning	R3
I couldn't reach an initial settlement proposal	R3, R4, R5, R10
I wasn't able to understand what was meant	R10
There were steps which I couldn't perform	R6

In the last group of the examination, on a typical problem of programming contests, respondent R1 stood up positively, showing a deeper understanding of the subject, and its application in the context of the problem presented, despite not being sure that the solution he found was the best. This is a core competence to be developed by all students of this case study, in a course on Algorithms and Data Structures. R7 stood in a significant distance from R1, followed by R2 and R6. In this group, as in others, the respondent who had more difficulties was R10, followed by R3, R4 and R5 who also showed reduced ability to apply knowledge to new situations. Thus, it's not a surprise that the more superficial approaches to the study lead students, whenever asked differently, to difficulties in understanding the meaning of the problems.

In the exam, in general, the respondent who stood with the largest number of core competencies to maintain, and with self-motivation to develop the subject, was clearly R1, followed by R7 and then R2 and R6, although the latter two have presented some weaknesses in the first group. The respondent with more difficulties in terms of the various groups was clearly R10, followed by R3, R4 and R5, although the latter three, with surface trends, presented skills to keep on the quiz, and R3 also in the second and third groups.

4) Post-exam reflection over key aspects to maintain or improve, or if the effort was worth it

After the reflections over how study habits have influenced exam performance, the respondents reflected over key aspects to maintain or improve in the way they prepared themselves. We observed the following:

- 20% (R1 and R2) defended the way they prepare themselves, since they considered to have obtained a good result, although R2 admitted that the effort did not pay, since the grade was below his expectations. On the opposite, R1, R4 and R10 considered their effort rewarding, since they learned things they did not know. However, both R4 and R10, which presented more weaknesses at the level of acquired key competences, considered to change their preparation way by making more exercises;
- 60% (R1, R2, R3, R4, R7 and R10) considered that the effort was rewarding, since they liked programming, with the exception of R2. On the reflection on the aspects they would change on the way they prepared themselves, R3 referred he would study more deeply certain parts of the course, and R7 that he would have made more exercises;
- 30% (R1, R3 and R7) defended that their effort paid off, since they got a better grade than the one they would have if they were not prepared, despite the fact that R3 did not present signs of having a good grade;
- 40% (R2, R5, R6 and R8) considered the effort and action was in vain, since they had a grade lower than they expected. On the reflections of R5 and R8 on what they would change in the way they prepare themselves, they mentioned making more exercises, while R6 would have paid more attention to the quizzes;
- At last, also R9 did not felt any advantages on the effort, considering that he did not have time to prepare for the exam. Still, he referred that he would have made more exercises, if he had had time.

In this case we can conclude that a significant percentage of the respondents assumed the responsibility for bad study habits, caused not by the lack of study hours, but for the lack of a deep study on matters that require more than superficial knowledge. In this case they all agreed that the exam was within reach for most the respondents, and that it covered the subject discussed in the course, in the lectures and in the labs.

III. CONCLUSION

The set of results presented in this paper may not represent the reality of what is happening in programming courses that are part of Computer Science programs in Portugal. Nonetheless, we believe significant and interesting. The study reveals that, despite concerns expressed by respondents for personal achievement, through the attainment of academic and professional success, and autonomy and independence of families, and a favourable dispositions for the study, only a comparatively small part (21%) of students of the first year programming course we analyzed achieved competencies and skills necessary for writing programs with the required in-depth understanding, which requires more than a superficial knowledge, for full success in this subject. The exercise of self-reflection carried out by these students on their study and learning habits through b-learning supported by an automatic judge reflects the skills of self-knowledge that are part of the experiments and experiences in university. Indeed, they are key skills for the current knowledge society.

It is important that each student remain aware of both the critical points for the development of his high-level skills and of his abilities to manage his one academic path, so that he can prepare himself to successfully face the challenges of university life and reach the goals he has set for himself. It is interesting to note that if a student considers lack of effort as one of his critical points, this understanding will favour him since he knows he has to work harder. Nevertheless, if he has a lack of appetence for programming, a condition that is difficult to overcome by reason alone, he will feel that he is not able to control the situation and his chances to succeed are less.

We conclude by presenting the competences of the more successful respondents, that have emerged of this case study: a) self-motivated to carry out the various course activities, to formulate their own questions and to work independently, b) self-motivated for wanting more than obtaining minimum passing score, and for not procrastinating success in the course, c) self-disciplined and rigorous in planning and implementing activities, as well as in meeting the deadlines, d) with good work habits and effective study strategies, e) with ability to program, f) with handling capabilities of the technology available on the platform, g) with a desire to learn and participate in the forums and in the class room, h) with the ability to communicate through the technology available on the platform or in person.

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Assessing Competency in Undergraduate Software Engineering Teams

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Abstract - **From 2005, Active Learning in Computing partners Newcastle and Durham University (ALiC), part of the UK CETL initiative,[1], introduced a collaborative learning model of Software Engineering to level 2 Computing Science students that reflects global industry practice by focusing on cross-site software development. Assessment for this effort focuses on measuring students' development of both the technical and transferable skills associated with the practice of being a software engineer. However, it is often difficult for the student to perceive and articulate what skills they have learned during the project based on marks and feedback from lots of separate elements of coursework. In this paper, we propose that assessment of Software Engineering team projects should focus on the development of a range of competencies that could be measured in a style that relates directly to professional performance appraisal. We describe the current assessment methods we use and then outline a set of alternative competencies and appraisal methods that could be used to help staff and students better evaluate levels of achievement and skill development in qualitative terms during undergraduate team projects in Software Engineering.**

Keywords: Software Engineeering, Competency, Skill development

I. INTRODUCTION

The Centre of Excellence in Teaching and Learning, (CETL), Active Learning in Computing, (AliC), which commenced in 2005, is a consortium of North East UK universities comprising of Durham University (CETL lead), Newcastle University, Leeds Metropolitan University and the University of Leeds. The initiative aims to identify and enable ways in which students can become more actively engaged with the Computing Science curriculum in their learning. Through promoting project and group-working, ALiC has implemented new learning approaches, enabling students to move towards independent learning guided by appropriate support materials. To that end, AliC partners Newcastle and Durham have introduced a collaborative learning model of Software Engineering to level 2 Computing Science students that reflects global industry practice by focusing on cross-site software development. Industrial software is often produced clollaboratively between teams located at different geographical sites. The pedagogical aims of this cross-site collaboration activity are therefore: to give students an insight into Software Engineering in an industrial context; make problem-solving more realistic in student team projects; allow staff and students to use and evaluate various technologies for cooperative working and encourage the development of transferable skills such as communication, organising and team-working. Skills outcomes for the module at Newcastle were and still are listed as: initiative; adaptability; teamwork; numeracy; problem-solving; interpersonal communication and oral presentation. Overall, students have reported good learning outcomes in questionnaires and focus groups set up to evaluate the module design and their experiences. However, assigning marks to students during and at the end of the module on many separate pieces of coursework [2] means that student achievement is "abstracted into just a few numbers" so it is often difficult for students to perceive and articulate what software engineering skills they have learned and how these skills have developed during the project.

In this paper we describe the learning design of the cross-site development project. We review the assessment methods currently used to evaluate student performance and measure student learning outcomes. We propose that assessment of undergraduate team projects in Software Engineering should focus on the development of a range of competencies similar to those identified by Turley and Bieman, in conjuncton with the assessment of technical and team work products in a style that relates to professional performance appraisal [3]. This approach would give students a richer view of their achievements and a more useful and realistic performance review of how their competency has changed and developed throughout the project. We outline a set of alternative competencies and appraisal methods that could be used to provide staff and students with a better understanding of levels of achievement and skill development during undergraduate team projects in Software Engineering.

II. LEARNING DESIGN OF THE MODULE

At the beginning of the academic year, teams are formed from the Software Engineering module cohort at Newcastle and each one is then paired with a corresponding team at Durham. The major project task is the design and implementation of a large software system – (e.g. in 2005 the task was a tour guide application that could be loaded onto a PDA or mobile phone, in 2006 they had to create a logistics system for UK-wide distribution of personal care products and in 2007, teams had to develop a virtual geo-caching application). The aims of the module are to introduce the real world experience of team working and to provide practical experience of large scale software development. The teams of students work must work together as a 'virtual' enterprise across the sites for the whole academic year, using communication technologies to facilitate their collaboration.

There are some differences as to how Software Engineering is taught at Newcastle and Durham and through four iterations of the cross-site development project we have altered our practices to accommodate these differences and make the module a more cohesive experience for students in terms of our approach [5]. In our learning design for Software Engineering at Newcastle we 'front-load' the lecture component of the module and give our students 10 one hour introductory lectures on the basics of Software Engineering including an overview lifecycle models and phases and their associated techniques and tools. In operational terms, Newcastle take a problem-based learning approach – where students must rely on their existing programming knowledge and direct their own learning to solve the problem after the introductory lectures. Durham have adopted a hybrid-approach of traditional Computer Science teaching mixed with partial problem-based learning. They allow students to make all the team decisions but provide lectures and supervised laboratory practical sessions for the whole year to support the student development effort. The decisions the virtual companies are responsible include the definition and allocation of roles; the outline and implementation of a company management structure; the allocation of tasks to each member; the definition of the project plan; the choice of development methodology; tools to be used to deliver their software and documentation at the end.

Other deliverables for the project include coursework elements that are to be completed on an individual or local team basis e.g. a personal skills assessment, a contract, as well as product demonstrations. Each iteration of the cross-site model has seen minor changes to the nature of deliverables depending on the size of the cohort and also the nature of the problem to be solved. We have also evolved the way we teach the module each time it has run, making changes based on student and employeer feedback.

III. CURRENT ASSESSMENT METHODS

One element of the project that remains unchangeable is the need for each individual institution to take responsibility for the assessment of their students. It is likely that any institution's policy would dictate the need for this in a cross-site development project in order to ensure that institutional standards and integrity are maintained. Separate assessment protects students from the possible consequences of working with poorly performing students at another institution. In practice, this has meant that staff at both institutions work closely to ensure that students are fully aware of the aims and motivation of the assignment as early as possible and to ensure that a mark for any work product reflects their institution's students' contribution. Good assessment is fair, valid and reliable. We believe that it should relate to real tasks and realistic contexts, make expectations and criteria clear and provide feedback that allows a student to progress in their learning. It should also accurately measure skills and qualities that are practiced, demonstrated and improved throughout the student's learning experience.

There are a lot of assessments for the project throughout the year, (approximately 17). Before the CETL altered the learning design, there were 34 assessments each year. Table 1 illustrates the current set of assessments on the module and their type i.e. whether they are individual or team efforts. The rationale for having so many was to ensure that students had as many opportunities as possible to demonstrate and practice their skills and improve on their learning. Having many assignments also ensured that teams were kept busy and had enough work to distribute amongst their members. As part of the changes we made for the cross-site work, we also removed some of these assessments as some skills were over-assessed during the module in previous years e.g. presentation skills were assessed three times in pre-CETL iterations.

TABLE I. ASSESSMENT TYPES

Assessment	***Type***
Strengths Essay	Individual
Review	Team
Interim Requirements (F) *	Team
Group Structure	Individual
Contract	Team
Interim Design (F) *	Team
Presentation	Team
Project Plan	Team
Testing Strategy	Team
Final Requirements	Team
Final Report	Team & Individual
User Manual	Team
Final Design	Team
Software Submission	Team
Peer Assessments	Individual
Software Demo	Team
Monitor Observations	Individual

a. (F) – Formative Assessment – feedback only

The students are given formal templates for both the Requirements Specification and Design documents and allowed to submit a copy of these for formative feedback (as indicated by (F) in Table I before submitting their final efforts for grading. Students find this reassuring and it means they can make mistakes and improve their performance during the module, rather than retrospectively as in most forms of academic assessment.

There is a lot of emphasis in the module on documentation and on assessing team processes as well as products. At Newcastle team processes are *monitored* once aweek by members of staff who observe each team's formal meeting. These observations of interaction and participation are given a grade by the monitor at the end of the project and act as a weighting for the overall team mark. One reason for the emphasis on documentation are to help students to realise the importance of industry-standard notations such as UML in describing design. Having documentation that is assessed also ensures those students who are weaker in terms of coding proficiency can contribute in valuable ways to the whole team effort and be rewarded.

Table I also illustrates that there is a lot of joint assessment between sites. With each iteration of the cross-site work we increased the dependency between the teams for grades and the level of joint marking. The reason for increasing this dependency between teams was to increase their motivation to collaborate properly. However, the downside to the increase in dependency between sites is that it has also increased the level of anxiety students have about team assessment. This means that staff at both institutions have had to work hard on specifying common marking criteria that suits the aims of their separate programs and is also explicit in determining how an individual grade will be derived from all the cross-site and local team efforts.

A. Defining Individual Contribution

Students are often nervous or anxious about assessment fairness when involved in a group effort and cross-site working further exacerbated these fears. So, in order to ensure the student contribution at each site was differentiated clearly we mandated that students use a simple contribution matrix to help ensure recognition of individual effort. The matrix illustrates the type and amount of effort each individual contributed to an element of assessment, regardless of their base location. An example of a design document is given in Figure 1. In this matrix, the sections of the design document are outlined and then each student's contribution is defined in terms of whether they created the section, modified it or reviewed it in some way. The contribution matrices take a lot of effort to fill in for students especially for larger pieces of work such as coding but this ensures they are specific about the nature of the work they have done and the pieces of work they have contributed to.

Sections	Joe	Kirill	Michael	Tom
1.0 Introduction	C	M	R	M
1.1 Purpose	CMR	R	CM	R
2.1.1 PC Modules	Durham	Durham	Durham	Durham
2.1.2 PDA Modules	M	M	C	
3.1.1 PC Modules	CMR	CMR	R	
3.1.2 PDA Modules	Durham	Durham	Durha	

c=create
m=modify
r=review

Figure 1. sample contribution matrix

The use of these matrices helped to alleviate some of the assessment fears faced by students about working in a group e.g. the impact of non-participation of some members or the fear of not getting enough credit for their efforts. However, even though we were very specific about marking criteria and students reported that the matrices helped, they were still anxious about assessment so we decided to review all our assessment methods.

B. Coders and Non-Coders

We examined student grades from the Software Engineering module at Newcastle for 2 years before and 2 years after the implementation of cross-site work in order to determine how the changes we made had impacted on student performance. Because of the differences between cohorts each year and the subtle changes we made in each iteration to deal with operational problems, we could only infer this impact and note general trends. We analysed student grades, team reports and individual reflective reports from the years 2003-2007.

We found that, in general, students who did not contribute largely to the coding of the product during the project, received lower grades, on average, across all the years.

As can be seen in Table II there were 109 coders (34% of the total number of completing students) and 215 coders. The data indicated that 57% of non-coders scored less than their team's average mark and 39% of coders. These figures were quite worrying considering that the coding effort and subsequent software produced is worth only 5% of the total module marks available. The reason that the product is worth so very little in terms of grade percentage is because we want to emphasise all the other aspects of Software Engineering that are equally as important as the end product. Students tend to focus very much on the product and view programming as the only real important part of the work they are doing. As tutors we need them to recognise that Software Engineering is more than just programming, therefore we place more emphasis and give more academic credit to other deliverables and processes.

TABLE II. MARKS OF CODERS AND NON-CODERS FROM NEWCASTLE

Implement	1^{st}	2.1	2.2	3rd
No	26	42	31	9
Yes	67	91	46	8
Total	93	133	77	17

The intended learning outcomes for the module are divided into knowledge and skills outcomes as illustrated in Table III. These learning outcomes are sufficiently broad to cater for a range of abilities amongst the student cohort and terms such as *practical experience in design and implementation* (see Table III: Skill Outcomes column), should cater for all the processes associated with the design and implementation of a system, including the non-coding aspects. If a student has demonstrated these learning outcomes (to varying levels), then the differences between coders and non-coders should be irrelevant. The results from our analysis of marks made us wonder are coders better Software Engineers or even just better students? Ideally, for us, assessment in the module should be based on performance and not innate ability (although this is a factor that cannot be ignored) – however it is all too easy to specify a set of criteria for performance based on our perceptions of ability rather than what students actually do.

IV. Measuring Learning Outcomes

The worries over assessment of contributions the differences in marks between coders and non-coders set us thinking about what we really are assessing and what the student gets out of the module in terms of learning outcomes and skills. We had lots of questions that needed an answer e.g. does the mark generated by the assessment of all the deliverables and assignments give a true reflection of what the student has learned about Software Engineering? Is a mark for the project a sufficient indicator for an employer in industry of the skills a student possesses? Does the module give the student real tangible skills that can be used as soon as they go into a job?. Does it matter if they programmed the system or took some other role in the teamwork? Can students interpret what they have learned in the module as a realistic software engineering experience? Can students see how their skills have progressed and developed during the project?

TABLE III. module Learning outcomes

Intended Knowledge Outcomes	Intended Skill Outcomes
An understanding of the issues that relate to planning and execution of a team-based software project	Practical experience in the design and implementation of a large software system.
An understanding of the software engineering process, process mode ls and stages	Practical experience in issues such as te am structure, document preparation, project management.
	The ability to work as a member of a team, to fulfil appropriate roles within a team
	Evaluate own learning, progress and quality of solution objectively.
	Technical writing. Report writing
	Critical self-evaluation, peer evaluation
	Presentation of results.

As part of the module we run a series of mock interviews with real employers. Each student applies for a position, sending their CV and a covering letter. The employers taking part often complain that students do not present themselves as well as they could at interview. Some of the problems are definitely due to a lack of confidence but also many students focus only on their technical skills in the CV and at the interview and ignore the 'soft' skills that we also want them to learn during the project. Most employers want a more rounded individual with the potential to grow and change in the organisation, a self-starter that works well both in teams and on their own. So students need to be able to articulate what the module has taught them both in terms of technical software engineering skills and other transferable skills e.g. communication and leadership. One thing that we currently do well is get students to complete a self-assessment skills ticklist and essay at the start of the year. We give them a set of broad categories based on an old version of Belbin team roles [10]. Students are asked to identify their existing skills and where they might fit in the common stages of the software lifecycle e.g. would they fit into a design role, are there skills they have that could be used in all phases of development?

We ask the students to complete a self-assessment report at the end of the module (Final Report, Table I). This report encourages the student to reflect on their project experience and discuss any skills they have developed, improved or learned for the first time. They are asked to compare their initial skills assessment to their skill levels at the end of the project. Over 4 iterations of the project, by reading these reports and conducting focus groups with the module cohort, it has become clear that students do not always know the reason why they are doing a particular assessment or task during the project. Some students also have had difficulty grasping the importance of formative assessment of large work products and often fail to use the feedback we give them to improve their grades. Others have difficulty in articulating how their skills have changed or what new skills they may have gained during the project.

Our experiences tell us that students have not reached a critical understanding of many of the important aspects we are trying to teach them and we feel that this is caused by the nature of the assessment tasks we set them – they are, to some extent mismatched with what we are trying to achieve. According to Ambrose "the extent to which students engage in critical reflection in large part depends on the extent to which the assessment methods employed have developed critical understanding as their goal." [8]. We feel this is an area where our assessment design could be improved. Our assessments are too academic and bureaucratic in nature. Whilst work such as the Requirements and Design documents gives students practice using formal notations and techniques associated with Software Engineering, students receive numerical values and feedback for each single document or software item (which is collaboratively-produced) as a measurement of their proficiency and competency-levels in the discipline. This makes it difficult for them to get an overview of their personal performance as a software engineer. Individual assignments such as essays, presentations and reports don't really test or assess their practical skills – merely their reflective skills. Practical skills are treated as a group commodity and often assigned one grade or a weighted grade but the feedback is common to all. We use methods to derive an individual's marks for the large products, but not individual feedback. Observations made by monitors can be subjective and don't reflect a true picture of the practical work students do outside of formal meetings and class times. The *process* is not being measured as accurately as it could be and feedback to students needs to be more meaningful on an individual level in order to capture the wealth of learning they have experienced and give them a real sense of their ability as a software engineer.

V. Assessing competency

Competency matrices, such as those used by Smith and Smarkusky for self and peer assessment [6] could be used instead to capture learning and give students rich feedback on their abilities and skill levels. A competency matrix captures team knowledge and skills in various categories (process, communication, interaction, contribution and responsibility). These matrices then allow an assessor to assign a numerical range of proficiency in each specified competency – individuals are evaluated by selecting a class rank to indicate the baseline competencies expected of the individual. In this work, peers assess whether an individual has met the expectations, exceeded the expectation by various amounts or requires improvement (varying amounts of improvement can be denoted e.g. we have used first, second or third class performance). An abbreviated example adapted from the work of Smith and Smarkusky is given in table IV.

TABLE IV. SMITH AND SMARKUSKY'S COMPETENCY MATRICES

CLASS RANK	1ST	2ND	3RD
Process	Steps required to complete project		
Task Performance	Exhibits on tasks behaviour consistently	Supports others in completing tasks	Motivates others to independently stay on task
Leadership skills	Learns about leadership skills	Rehearses leadership skills	Exercises leadership skills
Communication	Oral and written means by which students share ideas and information.		
Shares ideas	Shares ideas especially when asked	Shares ideas readily	Mentors others in sharing ideas
Asks questions	Asks questions for communication	Asks questons related to prioject fundamentals	Asks question that directs conversation toward project solution
Interaction	Ways in which students interact socialy, their interpersonal skills, how they resolve conflicts.		
Team problem-solving skills	Uses critical thinking to develop a project solution	Encurages a team decision by examining project criteria and supporting evidence of each alternative	Uses ethodology to make a team decision and presents problem solution with supporting evidence from each team member.

Currently, our module learning outcomes for the Software Engineering Team Project are quite explicit in that we expect students to undertake roles, practice project management skills, communication skills etc. but in terms of Software Engineering competency – our assessment instruments are weak. Ambrose [8] suggests we need to provide an holistic view of a person's competency and for this to happen students need to develop self-efficacy where they can make judgements not on what skills they have but what they can do with the skills they possess. We do this in a small way at the start of our project, by getting the students to evaluate their skills in broad terms using a reduced Belbin form [10] that denotes broad team characteristics and behaviours team members might exhibit or possess innately e.g. an Investigator personality is good at finding things out, will be particular about finding new ways to solve problems etc. However, we do not retain the focus on skills in other pieces of coursework throughout the year or at the end. The focus on skills tends to get lost in the creation and assessment of the software engineering products that we ask the students to complete and the broad criteria that we use to assess them. Feedback for the module tends to focus on one piece of coursework at a time and does not give the students an overarching view of how they are performing during the project or at the end. Ambrose's work and the work of Marakas et al [9] in the area of measuring competency suggest antecedents to self-efficacy include verbal persuasion by a credible mentor, social comparison, (by observing someone else performing similar tasks) and the degree and quality of feedback and perceived effort can all enhance or decrease self-efficacy beliefs. As outlined by Ambrose, traditional measures of programmer's competencies include experience, professional references, training, transcripts and academic references, professional certification, written, oral and other demonstrative assessments during job interviews. These are all useful ways to find evidence of how well a professional is viewed and has performed in the field but don't really provide us with a guide to assessing students who are novices to the discipline of software engineering and whose degree program is not totally focused on software engineering. So how can we evaluate software engineering competency in an educational setting? We believe an adapted set of competency matrices could be used as part of an overall appraisal-like process for students throughout the whole project. Students would have to evaluate themselves and the performance of others in their team. They could be provided with examples of how to assess in a workshop before the project commences to instruct them on how to approach appraisal and fill in the matrices for themselves and others.

As these judgements could be subject to bias, other forms of assessment such as summative grading of work products, the use of signed and agreed contribution matrices for tangible deliverables and an individual report and interview at the end of the process would be used. The student evaluations could be used in conjunction with those of staff. Staff would use the same matrices and criteria to assess students as the students themselves and then compare matrices in order to assign grades based on a scale defining if they have met expectations, exceeded expectations or if they need to work on certain areas. This would give a sense of continuity, a transparency in assessment and a shared language for staff and students to discuss performance. This method would also give students some experience of 'social comparison'. Students very rarely get to view the results and feedback given to others and therefore find it hard to compare their performance to that of others in their class in a formal or managed way. A competency matrix would also give students early feedback as to their progress so they can correct poor behaviours. We could use the matrices periodically to get students to evaluate how they think they are performing along a set of pre-defined competency areas.

VI. Software Engineering Competencies

We propose that the competencies that should be measured via peer, self, formative and summative assessment are along the lines of those discovered by Turley and Bieman when conducting a study of exceptional and non-exceptional professional software engineers [4]. They identified 38 competencies including – helps others, willingness to confront others, responds to schedule pressure, focus on user/customer needs, team-oriented, writes / automates tests with code etc. We would use these in conjunction with the assessment of technical and team work products. Many of the behaviours Turley and Bieman identified with non-exceptional performance "can be viewed as the behaviours of inexperienced engineers" because a beginner "will be unsure of their own skills and capabilities" and therefore defining levels of proficiency or development in these behaviours should give our students more confidence as to how they have improved during the year. Suggested competency areas are 24 of the 38 that were identified by Turley and Bieman, (as illustrated in Table V).

TABLE V. Turley and Bieman's essential competencies

Team Oriented	Seeks Help	Helps Others
Use of Prototypes	Writes Tests with code	Knowledge
Obtains Necessary Training/ learning	Communication	Methodical Problem Solving
Uses Code Reading	Response to schedule pressure	Sense of mission
Attention to detail	Perserverance	Innovation
Desire to improve things	Focus on user or customer needs	Sense of Fun
Lack of Ego	Thinking	Skills/Techniques
Quality	Elegant and simple solutions	Thoroughness

The authors define competencies as "the skills, techniques and attributes of job performance" [3, 4]. They conducted an in-depth interview with 20 professional software engineers, (10 'non-exceptional and 10 'exceptional') who were employed by a major computing firm, (using the Critical Incident Interview technique as outlined by John Flanagan in 1954, the precursor of competency modelling) [12]. They also analysed competencies identified by software managers. The competencies they identified provide an alternative way of looking at the job of software engineering. The competencies are organised into four categories – *Task Accomplishment, Personal Attributes, Situational Skills and Interpersonal Skills*. In Table V, for example, Task Accomplishment competencies are Methodical Problem Solving, Obtains Necessary Training/Learning and Skills/Techniques. The authors provide examples of each competency e.g. Skills/Techniques is defined as proficient in using design techniques, debugging skills and easily makes technology choices. The authors concluded that although "most of the competencies cannot be used to distinguish between the exceptional and non-exceptional subjects, the derived competencies offer a unique view of the skills of professional software engineers" [3]. These competencies could be used to in conjunction with graded or evaluated competency matrices to help us illustrate the progression for the student on a software engineering module or even a whole software engineering program. This would mean they would get feedback on their skill development as opposed to only grades for a series of documents and work products that may not give them a complete picture of their learning or of what is expected in terms of the behaviour of a professional software engineer.

VII. The Student-Appraisal Method

We propose that an initial skills assessment is used before a team project begins in order to define the starting position, and past experience of students.

This will give students an idea of the skills they already have and how they could be best put to use during the project. At intervals during the project, (perhaps at the end of software development phases), staff could use the matrices to rate students based on observation of meetings and their performance in presenting or talking about their work. Students could use the same matrices to rate themselves and their team mates according to those competencies identified by Turley and Beiman, for example on:

- Using knowledge
- Researching, Investigating, Problem-Solving
- Communicating with the rest of their team – methods and quality
- Developing solutions
- Speaking and presenting in groups
- Technical appreciation – use of software, hardware
- Taking initiative and responsibility
- Understanding of main duties and responsibilities
- Their most important achievements of the phase of development
- Their planning and response to schedule pressures.

These matrices would help us gauge the level of confidence a student has in their abilities and could also help initiate a discussion of roles and possibilities for learning during the project. We would then use a further set of matrices during the project, to measure the new competency levels of the students and assign grades. The matrices would also help us determine target competencies for students to work on and improve during the rest of the project phases. The matrices could also help us determine the group level of competency and provide early interventions if teams are failing. This type of assessment, from self, peers and tutors (similar to an employee 360^0 appraisal review by subordinates, peers and superiors) would give students an insight into how their professional work will be assessed by employers and colleagues. The matrices would be used in conjunction with the traditional assessment of technical work products and tangible deliverables such as code and documentation. This assessment approach would also include an interview on experiences and skills at the end of the project. We believe that although an individual interview may add to the resource burden of teaching for team projects, the incorporation of an interview will give students a more rounded and personal review of their performance. All team project experiences are designed to give students a realistic experience of working on a large piece of software and an insight into what it is like to work on real problems within development teams. The proposed methods of assessment we outline here offer an opportunity for students to receive higher quality feedback on their progress and development as software engineers and to determine how to further develop their skills, in a safe environment – which is the point of most team project exercises in higher education at undergraduate level.

The work outlined here could be adapted quite readily for other disciplines and not just Software Engineering. The current matrices that we have created and proposed focus on skills and knowledge that has been identified in practice and in the literature as key to the work of professional engineers, however it would be feasible to identify generic skills and competencies required in team working scenarios for other disciplines. Rarely does a professional person work in isolation these days and generic skills such as communication, leadership, negotiation and problem-solving are required of most professionals in the modern workplace. These generic teamworking skills could be substituted in the matrices and used as a basis for the competency evaluation and the student appraisal method we have outlined here.

VIII. Conclusions

In this paper we have described our cross-site software development project and some of the difficulties students have with our assessment methods and with determining their progress and skill development as software engineers during the project. A lot of the problems that students face are due to our use of academic assessment methods that provide a numerical grade and feedback on separate pieces of work, some of which has been constructed by the team. We have outlined a new method that seeks to give individual students feedback on their progress during the project in a richer and more holistic manner. We have introduced a contribution matrix method to help ensure individual effort and contribution are noted and the correct grades attributed to each student. We review competency matrices and competency definitions outlined in previous work and propose a new appraisal method that uses self, peer and tutor assessment of alternative software engineering competencies and skills. We believe this new appraisal-style method will help students to get better feedback on their performance, make assessment criteria more transparent and help students recognise and articulate their development and skills as software engineers more clearly.

IX. Further Work

Some of the positive impacts of the cross-site work described here are greater students' awareness of how differences in working practices, organisational culture, team structure, task allocation and project management styles between teams can impact on project outcomes. However assessment and feedback are areas that need improvement. We are continuing to develop and refine our competency-based approach to assessment and hope to develop a wider framework for assessment of undergraduate software engineering team projects and automated tools to support them.

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Session 02B Area 3: Knowledge and Competencies Management -

A knowledge based analytical model of propaedeutic cycles for higher education in Colombia

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The influence of design problem complexity on the attainment of design skills and student perceptions

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Business and Management Competency of Engineers: Curriculum and Assessment

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Authoring Learning Contents, Assessments and Outcomes in an Integrated Way

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A Knowledge Based Analytical Model of Propaedeutic Cycles for Higher Education: Linking with Media Education in Colombia

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Abstract—**A Knowledge based system model to face the new methodological strategy on Higher Education in Colombia is presented: the propaedeutic cycles. A great challenge is presented to Superior Education Institutions: to establish the link between traditional cycles: technical, technology and professional ones with the secondary, basic and media levels. Our solution is presented linking each phase with a propedaeutic component discussed in a model. The model is dialogically integrated by cognitive an informational components.**

A structural system to determine and analyze the cohesion and coherence of the propedaeutic cycles between competences and the curriculum knowledge. This construct enables curricular knowledge management inside the media and higher education. Several types of matrices are developed; firstly regarding columns: the longitudinal one in time (semesters); secondly the cross one grouped by curriculum subjects, (additionally each cell of them can be expressed by fuzzy values); thirdly regarding the structure: the input/output for optimization purposes.

An individualized model of student productivity to be integrated to counteract the stereotypes which considers the technical and technological cycles as relegated careers in higher education. This model is an intelligent knowledge based one which was validated with a software prototype just implemented in the FESSJ. This construct has as its mission the guarantee of quality assurance of student's propaedeutic cycles.

A multidimensional flexibility system supported on university autonomy for managing student, pedagogical, and curricular knowledge which enables the management of the heterogeneous and complex environment; this subsystem is intended to ensure continuity and permanence of the student.

The earlier is framed within a construct of curriculum knowledge and information. From this it is intended to reduce the high complexity of the harmonization and articulation of the propaedeutic cycles which face the universities when undertaking these projects.

Moreover, it is pursued to offer major clarity to the educational community and in this way to contribute to the democratization of the involved knowledge within this methodological strategic articulating efforts according to the policy of the Colombian Government which seeks not only to increase the educational population but also to a major access of the marginalized social population and of those of lower revenues in order to fulfill the right to information executed by the National Constitution of this country

Keywords- Propaedeutic cycles, media and Higher education, model, matrix of curricular coherence, student's model, expertise, knowledge management, intelligent knowledge based system, ICT

I. RATIONALE

The higher education system model by propaedeutic cycles that has been named FESSJ-PROP is a complex curricular architecture for implementation and analysis in all Higher Education Institutions in Colombia. A great challenge is presented to Superior Education Institutions: to establish the link between traditional cycles: technical, technology and professional ones with the secondary, basic and media levels. This Architecture is integrated to the Plan of Studies coherent of the three Propaedeutic Cycles; Professional Technical, Technology, and Professional. The model is supported on several dialogical components; structural components or matrix model for curriculum coherence verification and knowledge management, the management system of flexibility, and the student's productivity formation. The tests and validation of the model were initially supported on the rational on the use of the mathematical and computational instruments and, then, on the approach of the system measurement, the same rationale of the study theoretical frames, contrasting then, with the real application of the curriculum coherence matrix during the inspection on quality conditions of the Academy Peers for testing in Bogotá (March and April 2009) in all verified programs; additional a computer simulation model was designed and implemented for complementary validation. The consistence and the prediction power of the model was demonstrated along with the development of other information construct called iCOACH as a learning prototype , which is working to an experiential learning ; iCOACH is an intelligent system based on knowledge used as a student's individual productivity tool.

A. Objetives of FESSJ-Prop Model

- To reduce the high complexity of the propaedeutic cycle harmonization which are facing the Colombian Universities undertaking these projects
- To offer major clarity to the educational community
- To contribute to the democratization of the involved knowledge within this methodological strategic.
- To articulate efforts within the policy of the Government of Colombia that seeks to increase the educational supply to a major access of the marginalized social population and of those of lower income in order to fulfill the right to information and to the democratization of knowledge executed by the National Constitution.
- To improve the prospective scope as a tool for constructing future in institutions.

B. Specific Objectives

- To enable the curriculum analysis in time power, by periods, and in the knowledge power by areas and assignments.
- To quantify the university production in knowledge development for the student by propaedeutic cycle.
- To apply the new tendencies of engineering which are approached by models: model driven engineering, showing the good applicability of the model by propaedeutic cycles
- To enable the comprehension and management of the methodological strategic by propaedeutic cycles.
- To face accurately, the complexity involved in multiple dimensions.
- To demonstrate that the student productivity and higher education quality run hand in hand in each propaedeutic cycle.

C. Final Objective

It is intended to structure a computational pedagogical model from pedagogic models: the institutional one and the engineering based on multiple intelligences, defined in the Institutional Educational Project PEI.

II. Model Description

The model of the Higher Education System Model by propaedeutic cycles as mentioned earlier is complex curriculum architecture for analysis and implementation in all Higher Education Institutions. It is carried out by supporting on 3 components. Linear Model of Curriculum Coherence, Flexibility, and Student's productivity. These components are described next:

A. Linear Model of Curriculum Coherence

It refers the logical-cognitive relationships among the architecture parts of an educational system. It is as much an analysis instrument as a linear mathematical structure that communicates (all communication action is a pedagogical one), enabling the justification of a study plan and giving it as an organized and complex totality interlinking the interior and external coherency and consistency.

Among the objectives are:

- To manage knowledge enabling a morphologic analysis to a study plan on higher education.
- To eliminate inconsistencies and make viable the curriculum optimization of the PEI.
- To improve the prospective scope of the PEI.
- To quantify the production of the universities in the development of knowledge in students (competence culture) by propaedeutic cycles to redesign the expertise areas in each cycle as well as the know-how.
- To give priority to and classify the competence areas.
- To contribute to develop a curriculum without errors and ambiguities.
- To construct the input/out matrix or as a foundation of the optimization and structural analyses.

Among the objectives and scopes of the curriculum coherence linear model is:

- Non-complex comprehension of the methodology strategy by propaedeutic cycles.
- Optimization of university resources.
- The curricular coherence model is expressed as a matrix which is as much an instrument analysis as a lineal mathematical structure, enabling the justification of a study plan, which gives a sense as an organized and complex totality.

The curriculum coherence is the strategic alignment between a study plan with its objectives, justification, given the purpose and view, duly articulated with the PEI, The external coherence refers to the alignment of the educational style of FESSJ to the professional profiles and intellectual capital which demand the industry, the government, science, and technology in a global society. The model based on educational processes according to the curriculum study plan, where an assignment (including classes, workshops, tutorials, laboratories etc.) is associated to an expertise unit. The matrix method is of morphological type to obtain a system contradictions free without the unwanted entropy. The coherence also implies harmony, and articulation between teaching and apprenticeship, alignment, and synchronization.

The system diagram of the matrix model is expressed as follows: rows representing expertise of each level against columns in which the corresponding curricula subjects is arranged (See the Matrix bellow).

In the figure 1 the link is expressed as a propaedeutic component formed by the intelligent iCOACH in order to increase the student productivity in each cycle and also some assignments of connecting in order to meet the prerequisites of each cycle. It is suggested to have both a terminal cycle with their corresponding competences with and the cycle for following higher levels. We did the design for Systems engineering and it was presented to obtain the Qualified Register of the program.

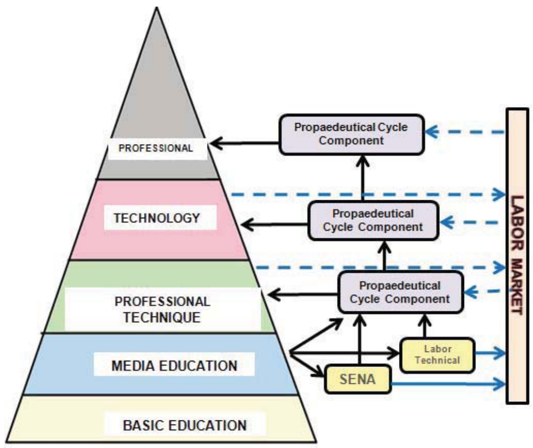

Figure 1. Propaedeutic component formed by the intelligent iCOACH

The Coherence additionally implies:

Characteristic: Holistic and integral view i.e. the entire complexity of the curricular system transcends knowledge in all its conceptual administrative, methodological, educational, normative dimensions.

Academy management is coherent with the PEI when the difference between the achieved in face to the wanted is null, curricular coherence.

The PEI is the expression of the proper philosophical comprehension of the educational task and it acts as definition of identity, exercising the university autonomy, recognized by the Constitution and Law.

B. *Matrix Description*

Several types of matrices were developed (figure 6); firstly regarding columns: the longitudinal one in time of the study plan (academic semesters); secondly the cross one grouped by curriculum subjects according to their applicability; additionally each cell of each matrix can be expressed as fuzzy values. The groups are: (1) Basic Fundamentals, (2) Scientific and technical fundamentals, (3) Professional Basic, (4) socio-humanistic and business, (5) Professional components, (6) Experimentation Scientific/Technical and (7) Advanced Topics, and thirdly regarding the structure: the input/output for optimization and structural analysis purposes.

The matrix presented bellow is formed by 4 blocks: Technical Labor Degree designed for students from basic education (9th grade), Professional Technical for students from high school (11th grade), Technology and Professional.

C. *Basic Matrix*

In general this matrix A is of M x N for knowledge management, where:

M rows represent the levels of the competence expertise of the curricular organization.

N columns represent the assignment subjects (knowledge offering) as functional and unitary areas educational processes involving classes, workshops, tutorials, laboratories ,etc of knowledge of the plan.

Each coefficient (cell), is of the binary type, e.g can be $a_{i,j} = \{ 0, 1\}$

It is 1, if exists direct implication between the expertise area and each assignment of the cycle study plan. It is 0 otherwise: values fuzzy dashboard in the basic matrix.

D. *Fuzzy Matrix*

On the other hand, each coefficient (cell) representing the cohesion and coherence of each assignment with the competence, can have other qualitative values / fuzzy logics, i.e.:

Ai,j = (null, middle, high) represented by colors in the matrix: [blank, red, blue].

This type of Matrix can be of two classes: the longitudinal in time (i.e. by academic semesters of the study plan and the transversal knowledge, where the curriculum knowledge of the subject is grouped as mentioned above. Below is presented a longitudinal matrix with fuzzy values just specified earlier..

E. *Curriculum Quantification from the Matrix: Cognitive Contribution*

The cognitive contribution of the j subject is obtained by the following matrix:

$$\sum_i a_{i,j} n_j = d_j \qquad (1)$$

Where n_j is the corresponding subject credits d_j is the cognitive contribution of the j^a subject for each propedaeutic cycle (columns).

F. *Other Metrics Obtained from the Matrix: Production*

The cultivated expertise is given by the production i as follows:

$$\sum_j a_{i,j} n_j = b_i \qquad (2)$$

Where b_i is the i^a production expressed as cultivated expertise for each competence unit (rows). For each cycle see bellow the corresponding values obtained.

	EXPERTISE	232
REE ON TECHNICAL LABOR	BASICS COMMUNICATION SKILLS	851
	BASICS SKILLS TOWARD ENTREPRENEURSHIP DEVELOPMENT	60
	BASICS SKILLS TOWARD ANALYSIS AND DESIGN OF SYSTEMS DE SOLVING.	2156
	BASIC SKILLS IN TELECOMMUNICATIONS AND ELECTRONICS	744

Figure 2. Expertise cultivated technical labor

	EXPERTISE CULTIVATED	
TECHNICAL-PROFESSIONAL	TECHNICAL SOFTWARE DEVELOPMENT	99
	PROBLEMS DEFINITION	108
	OPERATIONAL COMMUNICATION CAPABILITIES	63
	MAINTENACE AND EVOLUTION	49
	PROBLEM SOLVING	102
	ENTREPRENEURSHIP	89
	TRAINING ON RESEARCH	66

Figure 3. Expertise cultivated technical professional

The expertise demands the specific competence determination or high performance in a domain in each cycle.

	EXPERTISE	
TECHNOLOGY	GENERATION OF SOFTWARE SOLUTIONS	52
	SOFTWARE SOLUTION OF ENTERPRICE PROBLEMS	123
	ADMINISTRATIVE MANAGEMENT CONTROL	45
	TELEMATICS SOLUTION BUILDING	32
	ANALISIS/DISEÑO/ARQUITECTURAS EMPRESARIALES DE SOFTWARE	109
	NEGOTIATION OF SOFTWARE AND ENTERPRENEURSHIP	5
	TRAINING FOR RESEARCH AND INNOVATION	86

Figure 4. Expertise cultivated technology

The cognitive process is associated with learning instruments of more complexity.

	EXPERTISE CULTIVATED	
PROFESSIONAL CYCLE	ORGANIZATIONAL KNOWLEDGE	83
	CREATIVITY FOR THE IDENTIFICATION OF PROBLEMS AND THEIR SOLUTION	87
	SOLUTION ENGINEERING PROBLEMS	86
	ENTERPRISE ARCHITECTURE	65
	USABILITY SYSTEMS ENGINEERING	20
	ENTERPRICE AND ICT GOVERNANCE	71
	MANAGERIAL SYSTEMS	26
	ENTERPRICE INTELLIGENCE	36

Figure 5. Expertise cultivated professional

The expertise approach implies the competences development as a dynamic continuum and is associated to formation processes during long life of an individual and also are affected by technological changes and social practices. In the knowledge society the competences structure is variable and also intectually more demanded.

Other significant figure shows a measure of how well the different subjects of the Study Plan within a propaedeutic cycle work together to provide a specific expertise of functionality of the competence system displayed above in the transversal curricular coherence matrix.

III. Required Flexibilities per Propaedeutic Cycles

The actual Education System is rigid, hard and forces the student to reentry as contrasting with propaedeutic cycles in which the flexibility is mandatory. The curriculum is defined as the set of criteria, study programs, methodology and processes contributing to the integral formation and to the national identify construction, including aids the scholar human resources to put into practice the policy to carry out the PEI, the institutional educational project. The flexibility refers to the curricular, academic, pedagogical and administrative ones, that is, the use of the university autonomy to manage knowledge as well as the study plan for whom do not accomplish with the requirements to come up to higher cycles, and besides to relocate learning contexts supported by ICT.

Curricular flexibility is the structure defined as the content organization, methodologies, and selected vocational training to develop study plans of school programs in which the contents are selected according to their importance, pertinence, appropriateness, technological, scientific, social and economic impact on account of the competences wanted to be cultivated and developed in the technician, technologist, and engineer.

The structure has been provided with a solid common nucleus in each cycle and elective subjects which will consult the stage of this art. The broad experience of FESSJ in the first cycle consolidates the possibilities of this flexibility.

Academic flexibility is an open and dynamical organized system which intends to transform the rigid structures which are uncoupled as it corresponds, wherein prevails the integrated work in the application and search of knowledge, defining the professional area. An open system promotes self management and self regulation. The strategic alignment of an institution is an imperative: PEI

The pedagogical flexibility that applies the educational strategy as a coherent unified, and integrated framework of school decisions promoted by the educational model, underlies the mentioned self-regulation and self-control by a student in his learning enabled by the ICTs, which allows him to enter to diverse learning spaces and environments tending to new educational communicative and interaction forms and also knowledge access In the same way the controls on the student about how to reach knowledge are implemented via electronic, information, and cognitive micro-worlds cultivating the competences which were already explicated as well as the involved strategies in the educational model that:

- Considers the integration of Academic Credit units of each engineering aspect.
- Creates educational mastery linking education, research, and social projection as pointed by FESSJ, and
- Entails to new virtual spaces and contexts of personal autonomy in the students' learning, besides admitting that they performs project of each propaedeutic cycle.

Administratively, the flexibility supposes a range of possibilities to the educational offer within the culture of educational service to the research, the academic units which compose a outstanding institution as FESSJ from the policies which assigns it for relevant, important, and appropriate making-decisions according to the Development Plan 2008-2015. This flexibility entails to the necessary reengineering of the administrative processes for its ISO certification

To change, if required, the policies and flexible strategies, that is, it is necessary to state the actions in different university forms for the adjustment to the organizational change that implies to manage the Technique Professional cycle to a broader level the Technology and the Engineering level. The earlier requires thinking over the sense, purpose of the Management Model, the curricular and scholar systems, which are coherent, appropriate, and suitable to the FESSJ as a Higher Education Institution.

A. Student Productivity

Dropout university rates at national level are critic by its cultural, economic, familiar, and institutional implications. Several Higher Education Institutions have carried out studies, some of them by the Office of Higher Education, evidencing a prevalent and regular problem. For the first time, the design and construction of a tool iCOACH is presented. This one is based in knowledge and is powered by technology on artificial and computational intelligence apart from knowledge engineering as instruments of high information to record each student and assignment of the first semester. The architecture of the system involves three components: an edumatic constructor of tests and exams (professor's tool), a subsystem based on the student's modeling, and in another administration and security modeling. Several developments have preceded this project, which makes of the framework along with its methodology very reliable; on the other hand, it is intended to work according to international standards in order to obtain a good quality of the implemented product, to construct a system for checking the student concepts; the project was performed within Edumatic and the synergy Architecture and Software Engineering to set up the planning, the analysis, and the determination of the educational requirements to specify the design of an intelligent and systematic edumatic system with student's cognitive assessment for virtual modality.

B. Components

Several presentation matrices mentioned above were identified and grouped. Each of them is composed of various sub-matrices and vectors which highlights the coherence for each propaedeutic cycle. The feedback sub-matrix, corresponding to the objective cycle which allows quantifying the knowledge articulation of the current cycle of further cycles to strengthen the implicit competences. The feedforward sub-matrix allows quantifying the articulation of the current cycle processes and its feedback to the formation of the superior cycle competences. Within the vectors are those of production or cultivated competence vectors for each cycle and the cognitive vectors, among others. The solution is complemented with a system architecture framework to display the complete outlook of the curricular information or visor 360° of the academic logic, whose complexity deserves to be approached with accuracy methods and techniques.

IV. Conclusions

We have accepted the challenge proposed to the Superior Education Institutions: to establish the link between traditional cycles: technical, technology and professional ones with the secondary, basic and media levels.

Our solution is presented linking each phase with a propedaeutic component discussed in a model.

The Coherence Matrix is a kind of macroscopic of great quantity of curriculum information and competences, allowing the corresponding knowledge management.

This initiative sets up a way toward the architectural of information of IES on account of Colombia Education Law 1188 which is explicit about the curriculum complexity.

The model seeks to be an institutional learning instrument in the community and handles knowledge, thereby from these experiences is expected that IES go beyond of the simple management of the ICTs.

It is seen that is entirely feasible an ethos for research and knowledge in the technical and technology institutions. Likewise it is also seen that this policy based on propaedeutic cycles far from being a utopia really enables the democratic way to knowledge as proclaimed in the world summits on information society: Geneva and Tunisia

The construction of visor 360° not only as analytic instrument but also as support to architectural documentation a long with the model generates great expectation as credit of high quality in Higher Education with the prototype iCOACH, which has been performed. It evident one more time the flexibility of its professional implementation for the national academic community.

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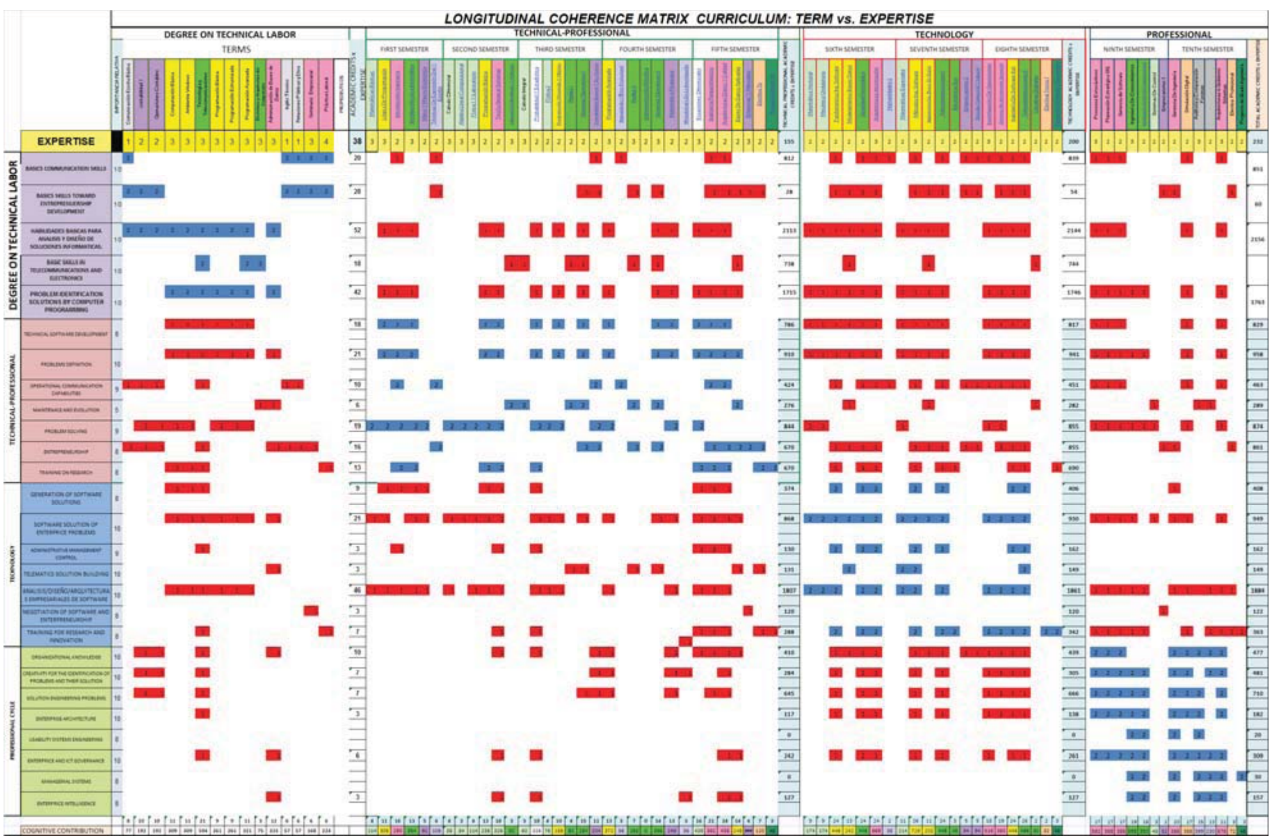

Figure 6. Matrix Curriculum: Knowledge vs Expertise

The influence of design problem complexity on the attainment of design skills and student perceptions

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Abstract—**One of the current educational challenges is how do we educate engineers to systematically solve open-ended real-world design problems? The capstone design course often plays a critical role in this, but there are numerous questions on how best to teach design and what are the characteristics of realistic design problems which provide excellent learning opportunities. This paper reports on a controlled evaluation of the effects of design problem complexity on students' ability to functionally abstract a design problem and its effect on their perceived value for variety of design methods. It is important for students to learn a systematic approach to the design process and to perceive its effectiveness. Students' perceptions and functional modeling skill are measured. Results, while preliminary due to limited sample size, indicate the complexity of the design problem is a critical factor in teaching design methods. There is a statistical interaction between the complexity of the design problem and opinion of functional modeling on their ability. Results also indicate that students who work on more complex design problems are more likely to expect to use functional modeling in the future. More complex design problems lead to a more positive student opinion. Further development of the functional modeling quiz is needed as is a larger sample size. Overall, results indicate that more complex design problem demonstrate to the students the effectiveness of the methods.**

Keywords- Design methodology; engineering education; functional modeling

I. INTRODUCTION

The Engineer of 2020 Report recognizes that creativity, invention and innovation are indispensible qualities for an engineer [2]. These skills must be understood, developed and taught. Critical research questions exist on how engineers develop their innovation skills and how innovation can be supported. The senior capstone design course plays an important role in teaching engineering students a systematic design process to enhance their innovation skills and guide them in applying their technical knowledge to real-world problems.

Systematic method approaches to the design process, such as the ones frequently taught in capstone design courses, have been shown to improve the process by increasing designer efficiency and the quantity along with the quality of designs [3, 4]. Teaching engineering design is seen as important enough to have dedicated special sessions and conferences [5]. The capstone design experience is viewed as a critical part of the undergraduate engineering curriculum but there is little agreement on how best to teach design to undergraduates [6].

This paper explores one aspect of the capstone design course, the design problem complexity and how it influences learning and student perceptions. The complexity of a situation (design problem) has been shown to affect skill development in other domains such as accounting [7]. One critical design skill is the ability to select useful abstractions, generate them and use the results to guide their designs [8]. Functional modeling is one class of methods focused on creating abstractions of a device. A function is what the device does independent of a particular form. For example, a car battery, a flywheel and a spring, all solve the function of storing energy (a battery through a chemical reaction, a flywheel through kinetic energy and a spring through mechanical material deformation). So a functional model would represent all three in the same manner as a device that stores energy.

The complexity of the design problem may also affect students' opinions and perceptions about the various design methods taught. Students' perception may influence how well they learn a particular design skill and the choice of using a particular design method in the future is often up to the designer. The paper employs a controlled experimental comparison of teams working on a more complex design problem (a lunar rover) to teams working on a less complex problem of only a single module of the lunar rover. The following sections provide additional background on the design course and functional modeling, then describe the experimental design, the results and conclusions.

II. BACKGROUND

A. Introduction to Mechanical Engineering Design MEEN 401

MEEN 401 Introduction to Mechanical Engineering Design is a two-semester capstone design course where students work on a year-long open-ended design project [9]. The course focuses on teaching systematic approaches to systems engineering [10]. The course contains one large lecture and studio sections of approximately twenty students. All students attend the same main lecture where the various design methods are taught and includes topics such as need analysis, functional modeling, interface identification, FMEA and project planning [9]. Students learn the design methods as they apply them to their design project.

The first semester begins with each team of students working on the same design problem, for example designing a lunar rover. Students typically work in teams of three to four in a class of approximately eighty to one hundred students broken down into design studios of approximately twenty students. During the first semester, each team identifies the needs, requirements and moves through concept generation for the system level design. Approximately half way through the first semester, each studio sections selects a final system level concept and then each team within the section works on one of the sub-systems, for example the life support system. The following semester each studio selects a particular sub-system for detailed design. This course design is in contrast to less complex designs that can be completed in a year by a single team of students.

B. Functional Modeling

Functional modeling is an abstraction of a design problem which focuses on what a device does, not the specific embodiment of it. There are multiple methods for functional modeling including the FAST Method, Hierarchical Functional Models [10] and Flow-Based Functional Models in the Function and Flow Basis [1]. Fig. 1 shows a hierarchical functional model which breaks the main function of a coffee grinder, “make coffee grounds”, into smaller pieces of “input power” and “chop beans”.

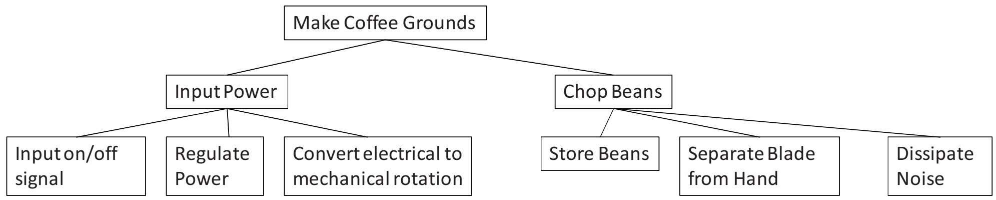


Figure 1: Hierarchical Functional Model for a Coffee Grinder

Another method for functional modeling is displayed in Fig. 2, a Flow-Based Functional Model for a Mars Rover Probe. The purpose of the probe is to break down rocks and analyze them. This functional model shows the materials, signals and energy that enter and leave the system. It also illustrations how the flows (materials, signals and energy) are changed by the functions.

The purpose of functional modeling is to focus the designer on what the device does and not on the specific form of a solution. It also reduces design fixation on a particular solution and assists with breaking down the problem into smaller pieces which can be more easily solved.

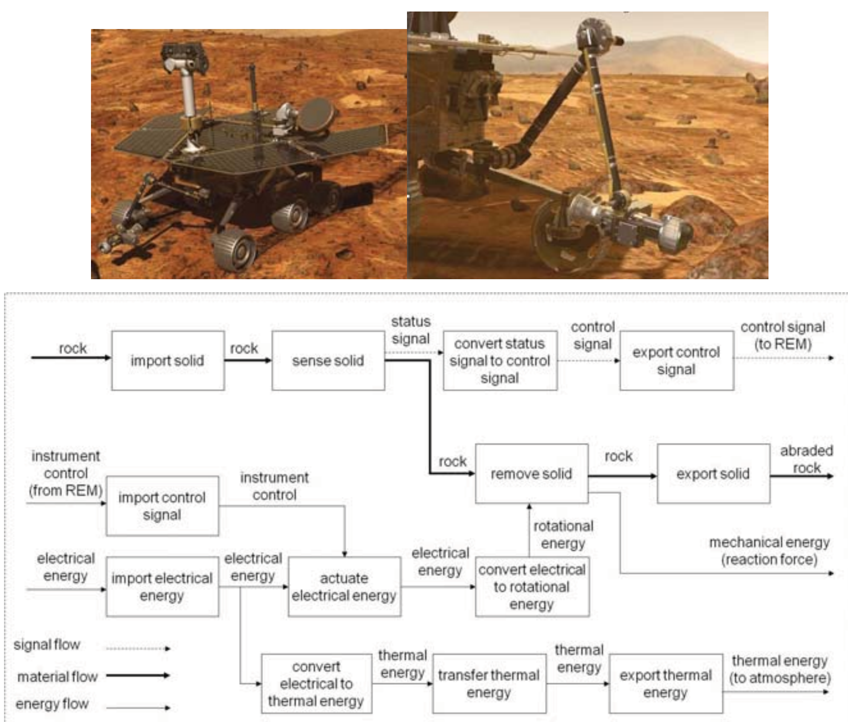


Figure 2: Flow-based functional models for a Mars Rover Probe shows how materials, signals and energy flow through a device and are acted on by the functions [1].

III. METHOD

A controlled between-subjects experiment measures how the complexity of the design problem affects student learning and perceptions of the methods. We make the following hypotheses based on the literature and discussions with experience capstone design instructors:

Hypotheses

Functional Modeling Skill Hypothesis: Students who work on a more complex design problem will achieve greater skill in functional modeling.

Student Perceptions of Functional Modeling Hypothesis: Students who work on more complex design problems will perceive functional modeling to be more valuable and are more likely to expect to use the method in the future.

Design Method Perception Hypothesis: Students who work on more complex design problems will generally perceive the design methods to be more valuable and will be more likely to expect to use them in the future.

Based on past observations it is believed that the more complex design problems such as the design of a lunar rover assist students in observing the need and impact of design methods and also provide an effective learning opportunity. It is possible that while students are learning the various design method, a more simple design problem would facilitate a deeper understanding of functional modeling.

A. Design Problems

The two design problems used to measure the effects of design complexity are (1) the more complex problem of a lunar surface vehicle and (2) the power transmission device (PTD), a module of the lunar surface vehicle. Both projects were presented to the students by an engineer at NASA who also acted as the project sponsor. The lunar surface vehicle design problem is to develop a device to aid crewmembers in exploration of the moon and transport cargo. The PTD's primary purpose is to provide mechanical power via a shaft to perform external work. Both design problems include more detailed specifications. For example for the PTD additional specifications presented at the beginning of the project included:

- shaft provides 75 horsepower at between 500-3000 rpm (variable)
- needs to be removable by crew (lightweight) with no/minimal tools
- electrical power for device provided by Rover
- extendable reach of 2 meters, capable of 500 pound lift
- swivels 360 degrees at Rover base with intermediate joint
- mechanism to be sealed with replaceable dust covers at rotating interfaces
- design to allow (not preclude) external attachment to:
  - *operate in-situ mining equipment*
  - *provide alternate power for rover movement*
  - *operate drill for recovery of soil samples*
  - *translate smaller cargo on/off Rover*
  - *play out/rewind communication/ power cables or large flexible antenna*
  - *assist in emergency translation of rover past obstacles (drive a wench/jack)*

B. Participants

A total of 64 participants were involved in the study, 48 in the Complex and 14 in the Simple Condition. Participants were recruited by offering them extra credit for filling out the method perceptions survey and their data were also correlated with a quiz which evaluated their functional modeling skill. Students were senior mechanical engineers at a large public university in the United States.

Students work in teams of three to four students. All students attend the same lecture for the design class and then are divided into design studios of 15-25 students. Each design studio has a different professor. Within each studio, one team was in the Simple Condition and the remaining teams in the Complex. Two of the Simple Teams were randomly assigned and two teams chose the Simple Condition based on very limited information about the design problem. All teams were supposed to be randomly assigned but this was not clearly communicated to the design studio instructors. The set-up of the teams allowed for the effects of the different studio instructors to be controlled.

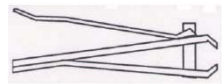
C. Measures

Two measures are used to evaluate the effects of the design problem on student learning. The first is a functional modeling ability quiz and the second is the students' opinions of the various design methods taught in class. Both measurements were made at the end of the first semester.

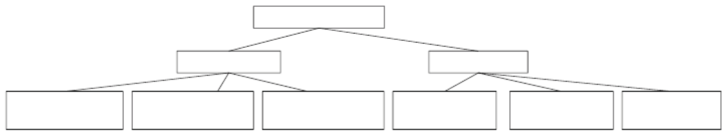
1) Functional Modeling Ability Quiz

A short quiz was created to measure the students' functional modeling ability (Sample questions in Fig. 3).

List four functions of the finger nail clipper shown.



3. Fill in the correct functions in the partial functional model for a coffee grinder from the list below.



Input on/off signal	Convert electrical to mechanical rotation
Input Power	Make Coffee Grounds
Separate Blade from Hand	Dissipate Noise
Chop Beans	Regulate Power
Store Beans	

In your opinion, what is the value of each of the following for a **DESIGN PROBLEM THAT REQUIRES AN INNOVATIVE SOLUTION?**

	Zero value	A little value	Medium value	High value	Extremely valuable	Don't Remember Method
Background research / Literature review						
Need Analysis						

In your opinion, what is the **GENERAL VALUE** of each of the following for a **TYPICAL DESIGN PROBLEM?**

	Zero value	A little value	Medium value	High value	Extremely valuable	Don't Remember Method
Background research / Literature review						
Need Analysis						

Figure 1: Example questions from the functional modeling skill quiz and method perception survery.

Students were given approximately 45 minutes to complete the quiz and it was given in-class. The quiz was created by the first author for evaluating the students' functional modeling skill and this was the first time the quiz was implemented. Quizzes were scored by a teaching assistant.

D. *Students Opinions of the Design Methods*

A survey (Fig. 3) measured the students' opinions of the various methods listed in Table 1. For each design method, the survey measured the student's perceived value for design problems requiring an innovative solution. The survey also measured their opinions on these same methods for more typical design problems (design problems not requiring innovative solutions). The students' expected future use was also measured for each method. Perceived value and expected future use were scored on five point scales from zero value to extremely valuable (zero value, a little value, medium value, high value, extremely valuable and don't remember method) and from very unlikely to very likely (very unlikely, unlikely, neutral, likely, very likely and don't remember method), respectively. Do not remember method was included so that students' only gave their opinions for methods they remembered. Newton's Law and the Bernoulli equations are controls since it is expected that especially for Newton's law all students would see this as valuable and expect to use it in the future if they become engineers.

IV. RESULTS AND DISCUSSION

Much of the focus of this study is on how well students learn functional modeling and their opinions of various design methods. Students who worked on more complex design problems were significantly more likely to expect to use functional modeling in the future (Fig. 4). Since the opinions are on a five point ordinal scale, Wilcoxon's Rank-Sum Test [11], a non-parametric statistical test, evaluates the statistical significance (Wilcoxon's Rank-Sum Test W_s=351.0, p=0.1 [12]). This does indicate that the complexity of the design problem does have on influence on student's perceptions of the method. As students leave the classroom environment and move into industry, it is often the designer's choice to use a particular method or not. Therefore it is important to understand students' impressions of the various methods.

Table 1: Methods [10] measured for Students' Perceived Value and Expected Future Use

Methods
Background research / Literature review
Need Analysis
Function Structure
Brainstorming
Identification of Interfaces
Failure Modes and Effects Analysis (FMEA)
Work Breakdown Structures
Drawing Trees
The general systematic approach to design taught in this class.
Newton's Law F=ma
Bernoulli's Equation

No significant difference is observed in students' functional modeling skill as a result of which condition they were in (Fig. 5). A rather small standard deviation (6.0) in quiz scores indicates that either the quiz is not doing an adequate job at evaluating students' functional modeling ability or the students' do not vary significantly in this skill (Fig. 6). There is significant range in the students' scores from 15 to 44. Further examination of the quiz results on an individual question basis and validation of the quiz is needed. Based on instructor observations the skill of the students is believed to vary substantially so a better measure of functional modeling skill is needed.

It is also likely that a students' opinion of a method could interact with how well they learn a particular method. If they do not perceive it as valuable then they might not effectively learn a method. For the current sample, an ANOVA does show an interaction between the condition and their predicted future use [Condition: F(1, 54)=0.48, p=0.19, Future Use Opinion: F(4,54)=0.58, p=0.49, Interaction: F(3,54)=2.15 p=0.1 and MSerror=24.80]. This indicates that the interaction of the students' opinion and the design problem condition they were in has a significant effect on their functional modeling ability. The sample size for students in the simple condition is currently 14 so more data are required to draw conclusions.

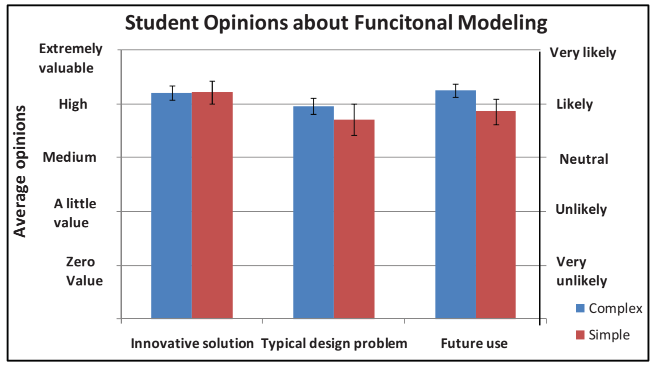


Figure 4: Students working on more complex design problems were more likely to expect to use this method in the future error bars are (+/- one standard error).

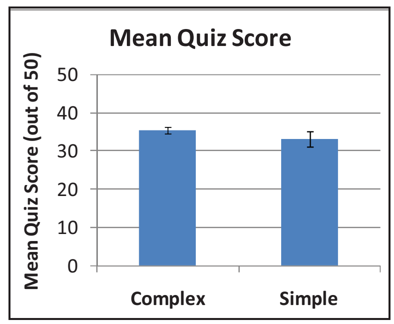


Figure 5: No statistically significant difference in quiz scores but the Complex Condition tended to be higher (error bars are +/- one standard error).

A. General Trends In Student Opions Across the Method

The complexity of the design problem does appear to have some influence on students' perceptions of the design methods (Fig. 7-9). Work Breakdown Structures show a consistent pattern across the three perception measures, students in the Complex Condition expect to use it more often in the future and perceive it to be of greater value than students in the simple condition. Only the perceived value for a typical design problem is statistically significant and the rest are close (future use W_s=353.5, p=0.17; innovative design problem W_s=308.5, p=0.17; typical design problem W_s=328.0 p=0.10). There is also a significant difference for expected future use of drawing trees (W_s= 254.5, p=0.03). The design methods are also generally seen as more valuable for design problems that require an innovative solution as opposed to more typical problems but there are no general trends across the design methods comparing students in the simple versus more complex design problems.

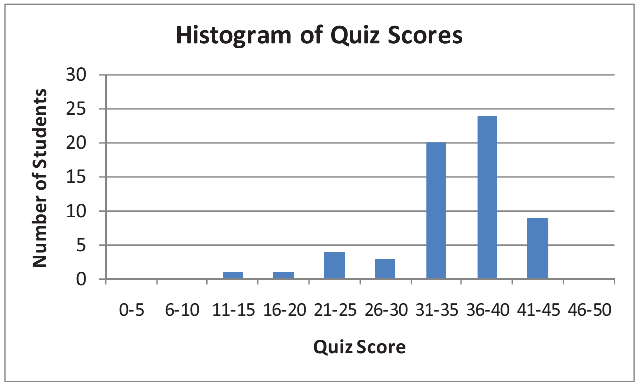


Figure 6: The scores are biased toward the high end of the scale with realively low variance (S.D.=6.0).

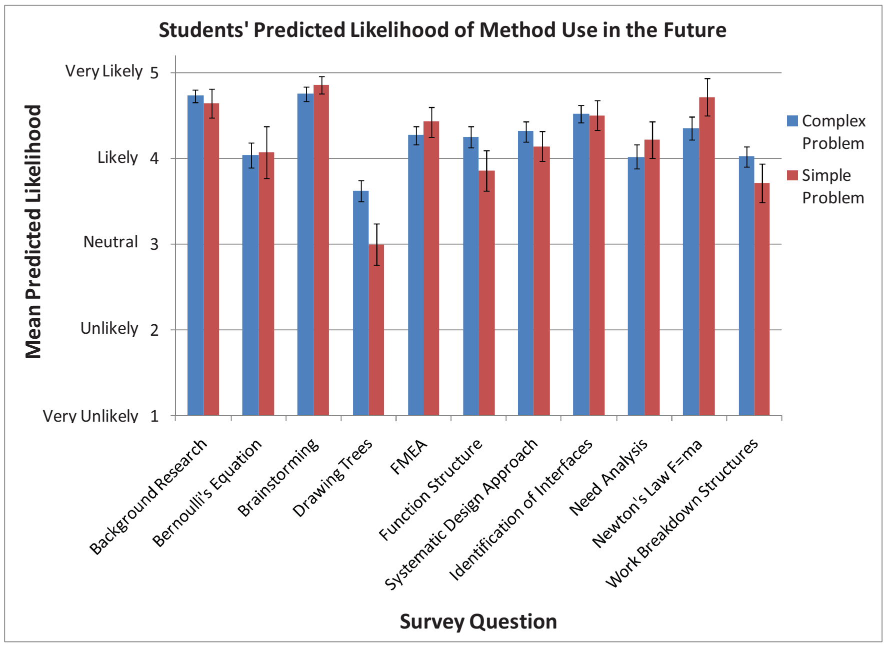


Figure 7: In general, for typical design problems, students' opinions did not vary depending on the type of design problem they had. Some methods did show statistically signifcant difference (error bars are +/- one standard error).

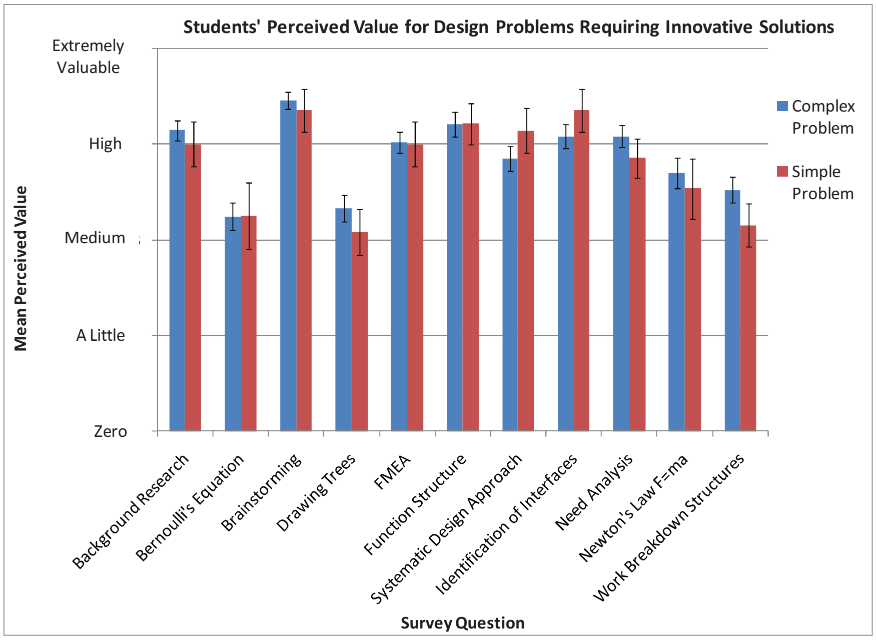


Figure 8: In general, across the different design methods, students' opinions for a method's effectiveness for problem requiring innovative solutions did not show any general trends with respect to the type of design problem they had. There are statistically signifcant trends for some of the methods (error bars are +/- one standard error).

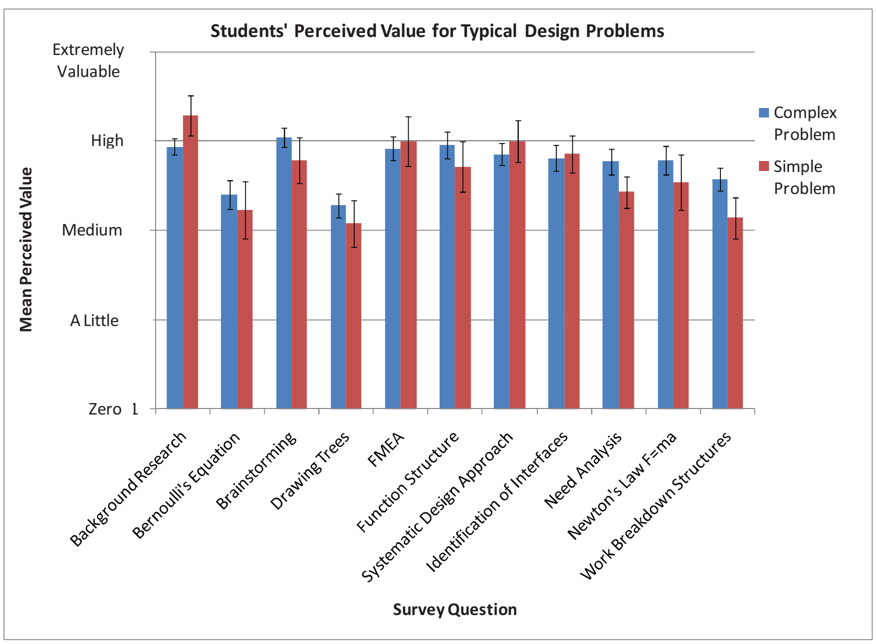


Figure 9: In general, for typical design problems, students' opinions did not vary depending on the type of design problem they had. There are statistically signifcant trends for some of the methods (error bars are +/- one standard error).

V. Addressing the Hypotheses and Recommendations

Functional Modeling Skill Hypothesis: The interaction of the complexity of the design problem and the students' perceived future use does significantly affect their functional modeling skill. A larger sample of students in the Simple Condition is required to further confirm this results since the current sample size is limited. This study cannot determine if there is a causal relationship between the students' opinions and their attainment of functional modeling skill. It is possible that if students' do not perceive functional modeling to be a valuable skill then they also tend to put less effort into learning it.

Student Perceptions of Functional Modeling Hypothesis: There is some indication that students who work on more complex design problems will be more likely to expect to use the method in the future and this was statistically significant. There was no evidence that students with the more complex design problem valued it more.

Design Method Perception Hypothesis: In general, students who work on more complex design problems do not place greater value on the methods nor are they any more likely to use them in the future. Some of the methods show trends of greater perceived value and students expecting to use them in the future more often but these are not statistically significant with the current sample size. Future work will continue to investigate this issue.

Recommendations: When the goal is to teach students the design methods, for example in a first design methods & theory course, more complex design problems should be used. More complex design problems clearly demonstrate the effectiveness of design methods.

VI. Conclusions & Future Work

Effectively teaching students to design and apply their technical knowledge to solve real-world problems is critical. There is no clear consensus and little empirical data on what factors influence student learning and perceptions in design courses. This paper explores one factor that likely influences student learning and student perceptions of systematic design methods, the complexity of the design problem. Through a controlled comparison, this paper evaluates the effects of design problem complexity on student learning of functional modeling and their perceptions of various design methods.

The complexity of the design problem does affect student perceptions and their functional modeling ability. More complex design problems result in more positive student perceptions. Results indicate there is an interaction between student opinions and the complexity of the design problem that affects their functional modeling ability. This effect needs to be further explored with a larger sample size since in the current experiment the Simple Condition contained only 14 students. In addition, further improvements to the functional modeling measure are needed.

There are numerous other desired learning outcomes such as the ability to troubleshoot problems and make accurate assumptions that are not measured by the current study. This study evaluates a single design skill but many other skills are also critical to the design process. Future work will also focus on these other skills and other issues associated with implementation of capstone design.

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Business and management competency of engineers

Curriculum and Assessment

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***Abstract*— It is a global trend that those engineers who are proficient with the principles of business and management are rewarded with leadership roles. With the growing interdependence between technology, industry, economy and society, more opportunities will be available for engineers to exercise their potential as leaders, not only in business but also in the nonprofit and government sectors.**

In this paper, the following questions are addressed: What does it mean for engineers to have business and management competency? How can engineering schools prepare their students to attain the type of business and management competency demanded by industry? The analysis presented in this paper addresses the above questions in the following ways. First it defines the meaning of business and management competency for engineers. Second, it offers a minimum learning criterion for the business and management competency of engineers and a set of three learning outcomes of engineering management education. Third, this paper shows the results of an industry demand survey for engineering management education as well as provides a review of the global educational trends in this field in the U.S., Japan and Korea. Finally, the leading examples and lessons learned from engineering management education at Yonsei University are presented, and recommendations are made.

Keywords- engineering management; business competency; learning outcomes; accreditation

I. Introduction

It is a global trend that those engineers who are proficient in the principles of business and management are rewarded with leadership roles. Being able to understand both advanced technology and its corresponding management strategy is the key to securing a competitive advantage in any high-tech firm or industrialized nation. With the growing interdependence between technology, industry, economy and society, more opportunities will be available for engineers to exercise their potential as leaders, not only in business but also in the nonprofit and government sectors. Policy decisions in a technology-driven society will require the attention of leaders who understand the strengths and limitations of science and technology and their impact on society. What engineers design becomes a core component of the critical network of engineering systems, which affect physical, human, and political infrastructures. New levels of sophistication will be needed of engineers as decisions that define priorities and objectives for a community, region, or nation should be viable not only technologically and economically but also socially and environmentally [1].

In this context, it is now indispensable for engineering schools to equip their students with management skills and business leadership. However, current engineering management education is separately or only partially offered outside of traditional engineering curriculum. A survey in Korea shows that engineering students evaluate their undergraduate engineering education as only 50 out of 100 on a satisfaction scale. A major reason for the low satisfaction level is the impractical engineering education they received. The contents of the coursework were only remotely related to the real-world business problems that the students had to face upon graduation. Furthermore, the students felt that they needed to have more business and management competency in day-to-day corporate operations [2]. In order to meet this student demand, engineering management education should be better integrated with exiting engineering curriculum [3]. On the industry side, a majority of employers feel that educational support is currently insufficient for the enhancement of students' and their employees' business and management aptitude [4]. Engineering management curriculum must become better aligned with industry needs.

Designing an engineering management curriculum to meet the needs of students and employers requires an understanding of modern engineering work and the type of business and management competency expected of engineers. Also important is a well-defined framework to evaluate the success of the engineering management curriculum and continuous improvement of the learning contents and methodologies. Therefore, in this paper, the following questions are addressed: What does it mean for engineers to have business and management competency? What are the learning outcomes of engineering management education? How should one measure success in the proposed learning outcomes? Examining these questions will provide insight into prioritizing the business and management course contents that should be integrated with traditional engineering education and enhancing the learning achievement measured against the learning outcomes.

The analysis presented in this paper addresses the above questions in the following ways [4]. First it introduces the concept of business and management competency for engineers. Second, it offers a minimum learning criterion for the business and management competency of engineers and a set of three learning outcomes of engineering management education. Third it uses this criterion to establish a typology of emerging methods to support business and management learning for engineering students. Fourth, it introduces an engineering management curriculum of Yonsei University, as an example of a type of education experience that is expanding globally. Finally, the paper offers a test application of the learning criterion and learning outcomes by using them to conduct and present summative assessments of student learning in the Engineering Accounting course at Yonsei University, and to discuss the strengths and limitations of the current curriculum.

II. Business And Management Competency For Engineers

A. What Engineers Do in Today's Workplace

Science and technology are a source of product and service innovation and economic growth. Engineers apply the principles of science and mathematics to develop solutions that satisfy the technological and economic constraints of engineering designs. Their work transforms scientific discoveries into commercial applications that meet societal and consumer needs.

Engineers perform a number of tasks. They conduct research and development (R&D) in order to discover new technologies and apply them to various engineering systems and processes. Engineers are concerned with the design, production and operation of new engineering devices. Many engineers are engaged with new product development. In so doing, engineers must consider several factors. For example, they need to: precisely specify the functional requirements of a new system, design and test its components, integrate the components to produce the final design, and evaluate the design's overall effectiveness, cost, reliability, and safety.

In order to make sure the new systems meet various technological and standards, they conduct testing, which occurs in all stages of R&D and production. In addition, many engineers work in production or maintenance as they supervise production operations, determine the causes of component failure, and test the quality of manufactured products. Engineers also estimate and manage the time and cost to complete projects. Sales and marketing professionals work closely with engineers to assess user requirements and incorporate them into new products and services. Engineers are concerned with the economic, social, and ethical aspects of new products and services. Some experienced engineers are placed in management positions where their engineering background helps them examine technical aspects of a product and assist in planning its installation or use. Such engineers with managerial responsibility oversee all the tasks listed above performed by individual engineers and teams [5].

In most projects, engineers work in teams, whose size range from a few to hundreds of people, on a complex problem, such as designing computer chips or an aircraft. Teams usually include non-engineers such as technicians, marketing and service professionals. The team leader is responsible for communicating the progress and has to make sure that all of planning, developing, testing, and building is carried out correctly. In this regard, engineers must be good at planning so that money and time are spent efficiently on projects [6].

Because engineering work spans over all aspects of product planning, development, production, and even some degree of marketing, engineers must have competency not only in technical disciplines, but in areas of business and management. In particular, engineers must have an economic mind with which to view their engineering designs. Because of limited material, monetary and human resources, engineers are asked to maximize the technological performance as well as the economic efficiency of their solutions. If economic efficiency is ignored, engineering solutions often do not have practical value for the consumer market. To achieve economic efficiency, engineers must make strategic decisions including the purchase of capital equipment, target costing of new products and services, and investment sizing of engineering projects.

B. Maintaining the Integri in Today's Workplace

Science and technology are a source of product and service innovation and economic growth. Engineers apply the principles of science and mathematics to develop solutions that satisfy the technological and economic constraints of engineering designs. Their work transforms scientific discoveries into commercial applications that meet societal and consumer needs. The above discussion illustrates the importance of both technical and non-technical knowledge and skills for engineers. Among non-technical skills, the business and management competency of engineers cannot be over-emphasized in today's organizations. In 2007, over 50% of newly appointed executives in large Korean enterprises held engineering or science degrees [7]. Government is broadening opportunities for engineers and scientists to hold public service positions because technical knowledge is essential in many public sectors, including: health/medical services, energy/environment, transportation, communications, agriculture/fisheries and national defense [8]. Companies also look for interdisciplinary knowledge of both technology and management even when hiring R&D personnel [9]. These facts clearly demonstrate the ever increasing demand for science and engineering professionals with excellent management skills in this new economy [10].

C. Yonsei Engineering Management Curriculum

Drawing from this industry demand, Yonsei University College of Engineering developed an Engineering and Technology Management (ETM) curriculum to enhance the business and management competency of engineering students. To define the ETM curriculum, an analysis was carried out to describe the strengths and weaknesses of current engineering students in terms of their aptitude, skills and knowledge. Based on these and an industry survey, engineering management education should focus on teaching the following abilities: economic analysis skills, strategic mind for product development and marketing, leadership and professionalism, and organizational and human resource management skills. These skills are grouped into three areas: 1) corporate management, 2) industry and economy, and 3) strategy and leadership, so that engineering management courses could be designed for each area. Table 1 shows seven ETM courses developed through this process. In the corporate management area, Technical Human Resource Management is offered to enhance students' understanding about the strategic management of organizations and human resources (scientists and engineers in particular). Engineering Accounting combines traditional financial accounting with cost accounting for engineers and provides engineering students with a fundamental understanding of the economic impact their R&D activities have on profit-making. Engineering Economics, which mainly addresses the economic valuation of technology and engineering systems, is offered in the industry and economy area. Techno-Leadership and Entrepreneurship is a course for the strategy and leadership area that sculpts the mind of a leader and entrepreneur to create new value in corporate and government organizations.

These courses are created to cultivate engineering students' aptitude, skills and knowledge in areas where they have weaknesses and industry demands are strong. They are electives integrated with engineering accreditation so that students can take up to two courses from the ETM curriculum during the sophomore to senior years. With this curriculum, Yonsei University, a leading engineering school in Korea, has been offering seven ETM courses for over 800 undergraduate students every semester. An increasing number of engineering schools in Korea are offering engineering management courses as part of their core electives. For example, Ventures and Patent Strategy is the most widely-taught subject in Korean engineering schools, including KAIST and Seoul National University [11].

Table 1: Engineering and Technology Management (ETM) Course Development

Curriculum Areas	*ETM Courses*
Corporate Management	Engineering Accounting
	Technology and Product Marketing
	Technical Human Resource Management
Industry and Economy	Engineering Economics
	Economic Trends and Business Opportunities
Strategy and Leadership	Techno-Leadership and Entrepreneurship
	Ventures and Patent Strategy

III. A Learning Criterion For Business And Management Competency

Drawing on the discussion of the previous sections, the proposed learning criterion for the business and management competency of engineering students is as follows:

Through course instruction and participation, students will acquire the knowledge, ability, and mindset to design economic engineering solutions efficiently and effectively with market and customer orientation.

Learning criteria are broad statements that guide the development of learning outcomes, which then guide the creation and assessment of courses and curricula that are designed to help students satisfy the criteria [12]. The words economic and efficient mean minimizing resource waste or cost input while meeting the target goals for scheduling and performance. Unlike the traditional cost-plus pricing method where materials, labor and overhead costs are measured and a desired profit is added to determine a selling price, an acceptable price for a new product or service is determined based on market information. Then, a target cost is the maximum cost that can be incurred on a product while the firm can still earn the required profit margin given the particular selling price. Thus engineers should be able to reduce the overall cost of a product over its entire life-cycle. Engineers also need to view the financial statements of their company and determine how the engineering division could help improve the financial performance of the company.

The word effective is closely tied to the capability to manage engineering teams successfully. Engineers must communicate with all the stakeholders involved in a project as to what actions are to be taken, by when and how much money can be spent on each activity. The engineers and related members get together regularly throughout the project to check the progress and to deal with any issues that may come up. Thus good project management, which also necessitates leadership and strategic employment of technical human resources, is the key to success in any engineering work.

Finally, market and customer orientation leads to the capability to design new systems to meet the needs of the customers and to have market power in order to generate significant revenue. Engineers should care about how new products and services will be marketed to target customer groups and increase sales. Engineers should also utilize their R&D results to generate revenue in a variety of other ways. The revenues sources include not just final products and services but also patents, licenses and other interim results of the R&D work. In today's open innovation era where market and customer groups quickly expand as firms look to advance their technology through the use of external ideas and knowledge [13], it is vital for engineers to seize every opportunity to make profits from their R&D work. The proposed learning outcomes for the business and management competency of engineers are:

1. Students will demonstrate substantial knowledge of the business operations (R&D, manufacturing, and marketing) as well as financial data (revenues, costs, and profits)

2. Students will demonstrate substantial ability to manage R&D teams, analyze customer needs and apply economic analysis.

3. Students will display a mindset to care about efficiency and value maximization in R&D work and to continue to make the engineering solutions evolve to fit the market demands.

The learning outcomes point to the importance of learning about delivering innovative engineering solutions efficiently and effectively and linking engineering work with market demands. The first component of the criterion and proposed learning outcome focuses on knowledge. A successful learning experience in business and management enables students to gain a factual understanding of how engineers in the real world deal with non-technical issues such as managerial, financial, and marketing issues and the ways in which such non-technical considerations impact their engineering work.

The second component of the learning outcomes is ability. An engineer with business and management competency is someone who has progressed beyond “awareness skills” to achieve “process skills,” which combine the new form of knowledge into day-to-day practices of engineering work [14]. The process skills, which are gained through practice, indicate the ability to apply various methods of economic engineering design and organizational management skills in engineering work.

The third component/outcome is mindset, which is more difficult to identify and assess, yet it is as equally important as the previous two. The term, “mindset” does not indicate inherent features of character or personality, but refers to learnable tendencies or patterned actions that are observable by others [13]. It is the mind to treat engineering work as an integral business function and an object of management in order to create winning products and services in the market. As a result, engineers gain a macroscopic view on all corporate functions where engineering work is aligned to meeting business goals.

The Accreditation Board of Engineering and Technology (ABET) provides only a general program outcome related to the business and management competency of engineering students. One of the ABET program outcomes states, “Graduates have a respect for diversity and a knowledge of contemporary professional, societal and global issues [15].” The Accreditation Board of Engineering Education in Korea (ABEEK) realized the need to make this statement more specific toward the non-technical competency of engineering students as it says, “Graduates have a broad education which is necessary to understand the impact of engineering solutions in a global and societal context…knowledge of contemporary issues in the society, economy, environment, and law [16].” However, neither one clearly states the competency in business and management for engineers.

In this context, it is now necessary to articulate what business and management competency is required of engineers. The key element in this learning criterion is the descriptive image of engineers who bring out innovative engineering solutions in the most efficient and effective way with market and customer demands in mind. The learning outcomes accept the view that acquiring knowledge and experience in business operations, financial analyses and technology management skills leads to the achievement of the business and management competency required of engineers. The engineers with business and management competency then design products and services that best respond to customer needs and therefore maximize the probability of success in the market.

IV. Preliminary Assessment of Engineering Management Education

The first step for engineering students to gain competency in business and management is to have concrete knowledge about business operations and experience in financial analyses and technology management skills. As displayed in Table 1 Yonsei University’s College of Engineering developed an Engineering and Technology Management curriculum with 7 foundational courses based on industry demands and the strengths and weaknesses of engineering students. The subject categories were corporate management, industry and economy, and strategy and leadership. This section introduces a preliminary assessment result of the learning outcomes of the Engineering Accounting course, which teaches students the principles of accounting in the ways engineering work is related to managerial and cost accounting and how corporate functions act together from financial perspectives.

A. *Course Outcomes*

By introducing the fundamentals of accounting and accounting issues that are related to corporate management and R&D work, the Engineering Accounting course helps students gain the knowledge and skills to analyze financial statements, manufacturing costs and tax issues from the engineer’s perspective. Three learning outcomes of the course are:

1. Students will demonstrate substantial knowledge of the fundamentals in accounting including the meanings of financial accounts and costs and interpretation of financial statements.

2. Students will demonstrate an ability to analyze and recommend ways to improve the financial performance of a company using various parameters measuring the financial outcomes of R&D and other business operations.

3. Students will demonstrate a mindset that realizes the importance of minimizing cost from R&D planning stages while maximizing the value of new engineering designs. They are conscious of meeting customer demands and aligning engineering work with the business goals of the company.

These outcomes are more specific to the topics of Engineering Accounting; therefore, they deviate somewhat from the learning outcomes introduced in Section III. The reason for this is that Engineering Accounting is only one of the 7 courses in guiding engineering students toward business and management competency. Fully attaining the outcomes presented previously is not easily accomplished by taking a single course in each topic, but the combination of the 7 courses is designed to equip engineering students with fundamental competency to deal with business and management issues that arise in engineering work. Rationalizing this leads to the more operative learning outcomes:

- Learning Outcome 1: In achieving this outcome, students come to understand accounting as a business language that expresses the state of the company through financial data expressed in certain standard formats. They also understand that accounting is a way to provide financial information to various stakeholders of the company, which engineering students have rarely thought about. The subject topics to help students achieve this first outcome include the role of accounting in corporate management, reading financial statements, and costing of R&D projects.

- Learning Outcome 2: The second outcome develops the ability to analyze the financial performance of a company using various accounting parameters. Students get exposed to a number of financial statements of different companies and are asked to analyze them. Students also learn to analyze the break-even points for engineering projects, to assess the financial performance of the engineering division, and to make various business decisions such as outsourcing. They also get exposed to the methods of activity-based costing, target costing, and taxation for start-up companies.

- Learning Outcome 3: Achieving outcome 3 is probably the most difficult for students in one semester. To broaden the mindset of engineering students, it is necessary to expose them to as many real world issues as possible. That way, students will learn to see how engineering work is related to broader areas in the company, economy and society. In Engineering Accounting, professionals (i.e. certified public accountants and accounting consultants) are invited at the end of the semester to tell engineering students about real world issues, why it is important for engineers to know accounting, and how engineers can proceed to business and management careers. The satisfaction level of such special lectures has been exceptionally high. The lectures of the invited speakers have had a positive impact on shaping the mindset of engineering students, and some engineering students even find a new career opportunity that combines their engineering knowledge with business and management.

B. Course Outcomes

To date, Engineering Accounting has been taught in five consecutive semesters. Each semester, around 150 students from all engineering departments are registered. Sophomores make up around 50% of the class, and a good number of juniors and seniors also attend the course for academic credit. Formats include lecture/discussion in large classes as well as 100 percent online lectures to help students preview/review class materials. Thus in-class activities focus on the presentation of important concepts in depth as well as exercises with accounting problems and short business case studies. At the beginning of each class session, a short quiz is given to help students grasp the fundamental concept of the day. A web board is heavily used for informal writing with student responses posted through online threaded discussions, autobiographical statements, and dialogues. Formal writing has included research reports, in-class exams, and reflections assignments. In addition to the Engineering Accounting textbook, a couple of introductory books, one of which is a business novel that depicts a career progress of a novice in accounting, are given for students to read over the course of the semester.

C. Assessment

Formative class evaluations have been conducted every semester since Engineering Accounting was first taught, and revisions to the course have been made. However, the evaluation questions were only general to assess the program outcomes of ABEEK [16] as discussed above. The faculty members who were teaching the 7 ETM courses realized that a simple program outcome statement of ABEEK was not effective to assess the learning of the business and management competency of engineering students. Thus, the learning criteria and outcomes, as well as a new assessment framework, were designed in 2007 in order to assess the engineering students' learning achievement in business and management competency. The focus of this section is on the summative assessment conducted in Fall 2007 to evaluate the extent to which engineering students accomplish the three learning outcomes for business and management competency mentioned earlier. The summative assessment included three instruments that map across the learning outcomes: a short pre/post quiz to measure learning outcome 1, a term project to measure learning outcome 2, and a final survey/reflection to measure learning outcome 3. Data from the final survey/reflection also provide additional evidence for learning outcomes 1 and 2. In this paper, the students' responses to an end-of-semester survey in an Engineering Accounting class are shown. A core set of questions was used and several additional questions were asked of students to assess the effectiveness of textbooks and teaching methods used. Only questions on this survey that were relevant to course outcomes are discussed below.

The survey asks students to indicate their level of agreement with a set of statements. A high percentage of students either “agreed” or “strongly agreed” with each statement. Roughly 85 percent of 90 students agreed that they “gained significant knowledge from this course about accounting and its importance for engineering work.” 80 percent agreed that they are “better prepared through lectures and homework assignments to consider financial aspects in engineering work” and 78 percent agreed that they gained “critical skills to analyze the corporate financial performance and suggest ways to improve weaknesses.” Importantly, the survey asks students to assess how their mindset has changed upon completing the Engineering Accounting course. 78 percent of the students agreed that they have “increased interest and passion in engineering management disciplines” and around 80 percent indicated that “the special lecture contributed to both deeper understanding and change of attitude toward the importance of business and management competency of engineers.”

The student survey results support the findings for learning outcomes 1 and 2, but more importantly, they provide evidence for learning outcome 3, development of a mindset to regard engineering work as having to improve corporate financial performance while minimizing cost input. The reflections that one student wrote in the survey stated, “I had no knowledge about accounting but this course helped me not only learn the principles of accounting but have the mind of a CEO to view engineering work as a critical business function.” Another student noted, “This course is a must for all engineering students. I am now more confident to have the knowledge and business-oriented eyes necessary throughout my career as an engineer and a future CEO.” Similar reflections are gathered in every semester. This clearly indicates the success of learning outcome 3.

V. Summary and Conclusions

The descriptive image of an engineer with business and management competency is someone who can successfully manage the development of innovative engineering solutions in an efficient and effective way with market and customer demands in mind. Through course instruction and participation in such activities as case studies, design projects and internships, engineering students acquire the knowledge in business operations, economic analysis and organizational management skills, along with a strategic mind for product development and marketing.

Based on the lessons learned over the last two years, the ETM curriculum of Yonsei University is being improved. First, it is necessary to diversify and customize the ETM courses to respond to the needs of each industry sector and engineering major. For example, civil and environmental engineering students feel that an environmental management course will be valuable to them. For architecture and construction engineering majors, a course in large-scale project management is necessary.

In addition, course evaluations suggest that specialized tracks be developed where students can take advanced courses in a field of their choice. For the case of Engineering Accounting, students were very interested to learn more about product development and target costing as well as taxation issues related to new business ventures.

A number of students indicated the need for more problem solving and case studies. It is not possible, however, to cover all aspects of theories, problem solving and case studies in class. It may be effective to break the class into small groups to hold help sessions. In fact, the large class size has been consistently pointed out as an area in need of improvement. More instructors who are familiar with engineering work and have competency in a business and management discipline should be hired. Also, as indicated earlier, undergraduate-level case studies should be developed and provided online so that students can access them at their convenience to augment their learning. Also, a global network of engineering management education should be expanded through more frequent dialogues and open exchange of information.

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Authoring Learning Contents, Assessments and Outcomes in an Integrated Way

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Abstract—**Developing learning material is a tedious task mainly due to two factors: their variety and their cycle of continuous update. Based on the utilization of DocBook for developing material, a solution is proposed to solve both problems. The proposal is to establish a special markup inside the DocBook format that permits to define multiple kinds of learning material in the same macro-document.**

Keywords- DocBook, authoring, learning material, learning assessment, learning outcomes

I. Introduction

In the context of learning material development there are two aspects that make this task cumbersome for the authors. The first one is the variety of the materials. Authors have to create units of learning for the students, scripts for the classes, test for assessment purposes, practical sessions, simulations, problem sets, flashcards (what we are calling *learning pills*), etc. Besides, all these documents can contain multimedia materials. Due to this variety of learning materials, their production becomes quite complex. The second problem is the cycle of updating materials. It is not easy to update all the references to a concrete subject that has changed. This is particularly a great problem in the technology environment because updates are more often than in other knowledge areas.

Some authors use standard formats for developing learning content. The DocBook format [1] is a schema maintained by OASIS [2] for books and papers that can be also used for the development of learning content. The objective of this paper is to present a special markup used in the DocBook format to provide it with a series of features that can solve the main problems of material authors. This markup also takes into account other aspects in a preliminary stage, like learning outcomes and objectives management and generation of evidences that prove these learning outcomes.

II. State of the Art

In [3], the advantages of using DocBook format files as a single source for authoring learning material have been presented. The use of XSLT transformations is presented as the main solution to the necessity of different formats to printed material (PDF) and web material (HTML). The packaging of these types of learning content using standards is studied in several articles, like [4] and [5]. In [5], the concept of reuse of existing learning documents is introduced, including several types of formats like Latex, DocBook and Word.

The idea of merging different types of information in the same shape is not innovative. Donald Knuth developed this same idea in his conception of Literate Programming [6]. This paradigm consists on writing programs in the order of demanded order and flow, not attached to any computer needs. Developed programs mix programming code and documentation. Literate program was subjected of a series of processing in order to obtain two outputs: one file with the code to be compiled and another one with the program documentation. This processing follows the same procedure as a demultiplexer (from one input, a set of outputs is obtained). One of the main ideas of this document is to present a mechanism that improve the work of content authors because they could, like in the literate programming paradigm, write learning material in any order as the ideas come to their minds.

The idea of defining a DocBook markup for including various types of content was also used in [5]. A variety of learning content can be extracted from the unique DocBook source (including the course itself) if the author follows a concrete markup during the authoring process: instructor annotations, slides including highlights of each section and extract chunks of learning material as reusable learning objects, that can be packaged following standards and integrated in Learning Management Systems (LMSs).

The rest of this section consists of the study of the main formats and tools used in this development. These are DocBook v4.5 as the basis format for material authoring, XSLT for obtaining individual material from the defined macro-document (as presented in next section) and ADA [7] as the tool used by authors in Carlos III University to produce learning multimedia materials.

A. DocBook

DocBook is a schema well suited to books and papers maintained by the DocBook Technical Committee of OASIS [8]. The DocBook Technical Committee maintains both SGML and XML versions of the DocBook DTD and XML versions in several other languages. It was originally intended for writing technical documents like books and papers, but it can also be used for other types of documentation like learning content for a course.

Initially, DocBook was a SGML document type but due to the emergence of XML a XML DTD was also developed. DocBook is a semantic language that provides authors with the possibility of publishing material in a variety of formats like

HTML or PDF. Dozens of organizations are using DocBook for millions of pages of documentation, in various print and online formats, worldwide.

DocBook provides a large number of semantic elements, which are divided into three broad categories as specified in [9]: structural, block-level, and inline.

Structural elements specify structural information like set (of books), book, navigational components (table of contents, references, index, list of titles), title, chapter, preface, glossary, appendix, section and so on. These include also meta-information elements like author, title, publisher, etc.

Block elements are elements like paragraph, lists, admonitions, examples, figures, tables, questions and answers and so forth. Not all of these elements can contain actual text directly (like xref component). Sequential block-level elements are expected to be rendered one below another.

Inline components are elements like emphasis, hyperlinks, phrase, footnote, mathematics, etc. They wrap text within a block-level element. These elements do not cause the text to break when rendered in a paragraph format, but typically they cause the document processor to apply some kind of distinct typographical treatment to the enclosed text, by changing the font, size, or similar attributes.

Finally there is a set of common attributes attached to all DocBook elements. The main attributes according to the development of the markup of this paper are:

- Role attribute contains a string used to classify or subclassify an element.
- The condition attribute provides a standard place for application-specific purpose.
- ID is an identifying string for the element. It must be unique at least within the document and must begin with a letter.
- Remap contains an element name or similar semantic identifier assigned to the content in a previous markup scheme.
- XrefLabel attribute holds text to be used when a cross reference is made to the element.

B. *XSLT and XPath*

XSLT [10] is a language for transforming XML documents into other XML documents. The original document is not changed; rather, a new document is created based on the content of an existing one. The new document is serialized by the XSLT processor in standard XML syntax. XSLT relies upon the W3C's XPath language for identifying subsets of the source document tree, as well as for performing calculations.

XPath [11] is a language for addressing parts of an XML document, designed to be used by both XSLT and XPointer. XPath also provides a range of functions, which XSLT itself further augments. This reliance upon XPath adds a great deal of power and flexibility to XSLT.

C. *ADA*

ADA stands for “Agile and Distributed Authoring” and is an authoring tool developed in the Telematic Engineering Department of Carlos III University. It is used for material production and publication in complex contexts: large number of resources (multimedia materials) and several authors working in a distributed environment.

ADA is also intended to deal with the authors’ problem of continuous update of learning materials and it provides mechanisms to solve this problem. For this purpose, it uses a distributed repository of material. If some parts of the material are changed, ADA will include these changes in all the subsequent produced and published documents.

III. Definition of the Proposed Markup

In order to deal with the material authors’ problems using DocBook, the inclusion of new features has been proposed. These DocBook add-ons can be implemented in two ways:

- Extending elements and attributes of DocBook format. That is, defining new tags as needed for the new behaviours that were required. For this purpose, a new namespace has to be defined and a DTD or XML Schema.
- Using a special markup maintaining the DocBook format taking advantage of general attributes. There are some attributes like condition that are application-specific and are not taken into account in the DocBook document processing.

The second option has been chosen because maintaining the DocBook format without extensions provides us with a series of advantages like the compatibility with DocBook editors and the validation of the XML can be achieved without extending the DocBook DTD or XML Schema. Thus, the methodology used has been to define a set of markup procedures using DocBook elements and attributes in order to accomplish the proposed objectives.

As commented before, a series of new elements have to be added (using its internal markup) to the DocBook format in order to improve the management of learning material in the same document. That is, the author will be able to develop different learning materials in the same document; thus, the creation process has been improved because the author can reflect whatever comes to his/her mind in the same document and just in time.

The author has to follow a set of markup instructions in order to indicate what type of material he/she is creating. A great macro-document is the result of this process, which will be post-processed conveniently in order to obtain the set of documents that the author intended to create. XSLT technology has been used for this post-processing purpose, so a series of templates (one for each learning material type) have been developed. In the development, the considered learning material types have been: units of learning (student lessons), assessments, learning pills and problem sets.

The markup defined for the DocBook format provides the following features:

- Possibility of indicating the learning outcomes associated to a content section.
- Definition of variables that can be evaluated all across the document. This feature alleviates the problem of continuous material update.
- Introduction of multiple choice and true/false questions that can be used in assessments. These special questions can include also other metadata like hints, duration or indication of incompatible questions.
- Possibility of defining learning pills in the macro-document.
- Creation of sets of open questions from this same macro-document.

All these features are explained in detail below.

A. *Learning outcomes indication*

Nowadays, one of the main required practices in the e-learning environments is the use of competences. One of the European projects that deal with this affair is the ICOPER project. ICOPER [12] is an eContentplus Best Practice Network that started its work in September 2008. As part of its objectives, ICOPER will provide a *Reference Model* and mechanisms to ensure European-wide user involvement, cooperation, and adoption of standards in the educational framework. To accomplish this goal, the project will systematically analyse the specifications and standards available and in use, to draw conclusions on their validity. In the context of the ICOPER project, an effort is under way to relate learning outcomes and assessment results through evidence records.

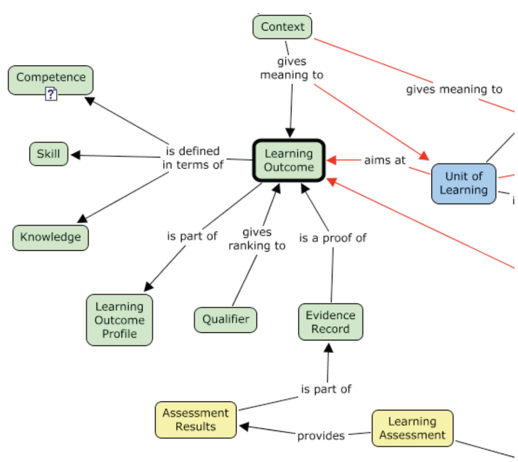

Figure 1. ICOPER Reference Model detail

As part of ICOPER Reference Model (see Figure 1), a conceptual map modelling key concepts for learning scenarios is being developed capturing key concepts and related specifications, but emphasizing on a competence-driven approach as well as the pedagogic underlying layout and the European-wide scope. It is important to define a set of concepts in the domain of e-learning, on one hand to clarify the terminology used and, on the other hand to establish the relationships between these concepts.

Following the European Qualifications Framework (EQF) learning outcome is a combination of competencies a learner should have (when successfully finishes a learning unit, course or curriculum) which include knowledge, skills and personal, social and/or methodological abilities. Learning outcomes are divided in three categories: knowledge, skills (know how to solve problems and tasks) and competences (proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development). Thus, in the following references to this subject the term “learning outcomes” will be used (that includes competences meaning).

One of the goals of this study is to provide a methodology to attach learning outcomes to courses. At a lower level, these learning outcomes are composed by learning objectives that can be attached to a chapter (or section of it). As explained before, this part of the development is in a early stage and only partially implemented. The DocBook markup used for learning outcomes is to define a paragraph (para) attached to the metadata of the section or chapter (i.e. section/sectioninfo/abstract) using the attribute role with value “learning outcome”. The competence itself will be defined as text inside this paragraph. In the post-processing of the macro-document the learning outcomes will be presented in the teacher lesson (but not in the student). In future developments, the questions obtained from this chapter/section that the student response correctly will provide evidence record that is a proof of a learning objective (and then of a learning outcome).

B. *Cross-reference definitions*

In the DocBook format there are some mechanisms used to reference parts of the content from some points of this same document. The *xref* tag is used for this purpose indicating the ID of the referenced element by means of the attribute *Endterm*. To include text the tag *xi:include* should be used, using attribute *href* to indicate the source file and *xpointer* to select a part of this file.

As this macro-document will be divided in several documents, it is necessary to define a way for not missing these references. Thus, the elements that will be referenced from other part of the macro-document will use the attribute role with the value id. In post-processing tome, this markup allows to get all this referenced elements and move them to all the generated documents. They will be placed as metadata of the chapter or section (i.e. sectioninfo/abstract).

This mechanism for cross-referencing text is a great solution for the problem of continuous material update because it allows not changing any reference to a concrete subject that has changed, but update just the original reference.

C. *Assessments questions*

DocBook format only allows one way of defining questions and answers: the qandaset element. This element is intended for Q&A sections of books or FAQs. So it is not suitable for assignments by itself (just for open answer questions without automatic correction). If learning material were being developed, it would be a good feature the possibility of defining other question types in order to be used in assignments and that allow automatic correction.

The FREMA model [13] is a reference model for student assessment scenarios that captures key concepts and related specifications in the e-assessment environment. The questions types defined by this model are the followings:

- Constrained: question whose response is constrained to a space of solutions. That is, the student does no need to write any words just selects an option from a set. Examples of this type of question are multiple choice questions (MCQ), multiple response questions (MRQ), true/false (TF) and matching.
- Constructed: question whose response is open, that is, it is constructed by the student. Examples of this type of questions are short-answer questions, essay, fill in the blanks (FIB), crossword and so on.
- Miscellaneous/mixed: questions that do not fit in the previous categories, like practice sessions, simulations, etc.

Taking into account this classification, the questions supported by DocBook are constructed ones. So it would be nice to have constrained response questions also available because they can be used to assess other learning outcomes and they allow automatic correction. Miscellaneous questions would be also appropriate and its inclusion will be developed in future versions of this tool.

The DocBook markup for this behaviour is the use of the attribute role to indicate the question type attached to a qandaentry entity. The new questions types that the defined markup allows are multiple choice questions (role=”MCQ”), multiple response questions (role=”MRQ”) and true/false (role=”TF”). The correct response indication has been achieved using the condition attribute in the answer entity that corresponds to the correct response with the value correct (condition=”correct”).

Another feature included related to the assessment is the possibility of indicating incompatible questions. That feature is necessary when the question wording is created in several ways (for example, to use it in assessment, problems or examples). In the metadata of the question (qandaentry/blockinfo/abstract) a paragraph (para) element is included with the role value of incompat (role=”incompat”). The content of this paragraph will be a reference to the question ID that is incompatible with the current question.

On the other hand, the assessment technique using questions is a successful and well-known strategy. It has been applied to assess the knowledge of student (summative assessment), but also to acquire knowledge during the learning process (formative assessment). Student assessment using questions is usually carried out at class, as a learning activity belonging to a course. This assessment type can be performed using intelligent tutors due to the advantages (effectiveness and utility) that they offer as explained in [14].

There are a variety of strategies related to the hint provision. The subjacent concept behind the hint provision is that the student can ask for help in case he or she were not able to solve a problem. Using hint, the student will have more possibilities to get to the problem solution following a reasoning process (discovering during learning process).

For all these reasons a hint system have been included in the question definition. This information is attached to the metadata of the question (qandaentry/blockinfo/abstract) in a paragraph (para) whose role attribute is declared as hint (role=”hint”). The content of this paragraph will be the representation of the hint that can be textual, an image, or whatever the author want to include.

In this way, it has been determined as convenient the inclusion of information about the time that a question is supposed to be solved. That feature provides the author with the possibility of estimating that time that a question is going to take to the student. Using a simple processing, the estimated time for complete exams can be obtained.

The duration of a question is marked in DocBook in the metadata section of the question (qandaentry/blockinfo/abstract) in a paragraph (para) whose role attribute is declared as duration (role=”duration”). The content of this paragraph will be the estimated duration of the question expressed in minutes.

D. Learning pills

Flashcard [15] is a set of cards bearing information, as words or numbers, on either or both sides, used in classroom drills or in private study. One writes a question on a card and an answer overleaf. Flashcards are widely used as a learning drill to aid memorization by way of spaced repetition.

A widely used method to efficiently use flashcards was proposed by the German scientific Sebastian Leitner in the 1970s. In his method, known as the Leitner system, flashcards are sorted into groups according to how well you know each one in the Leitner's deck. This is how it works: you try to recall the solution written on a flashcard. If you succeed, you send the card to the next group. But if you fail, you send it back to the end of the current group. Each succeeding group has a longer period of time before you are required to revisit the cards.

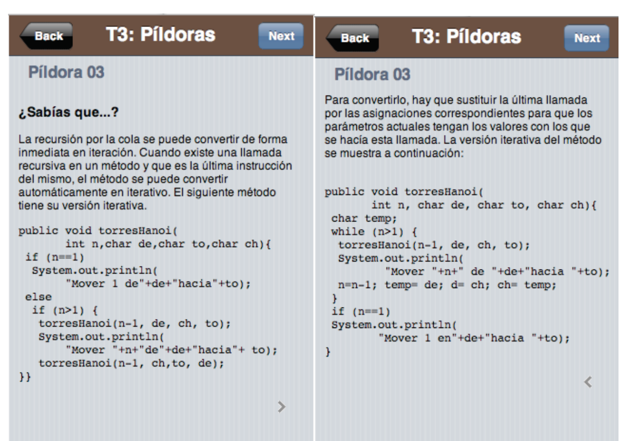

Figure 2. Learning pill example (front and back)

Leitner's flashcards is what is called learning pills in this article. But, instead of referring to physical cards we are referring to learning pills as electronic material (see Figure 2). They are constructed using HTML and JavaScript in order to achieve the effects of flipping the card and deck of cards management.

Regarding to the DocBook markup, block and inline elements are used like para or phrase but using the attribute role to indicate the learning pill question (role="learnpill_question") or he learning pill answer (role="learnpill_answer"). In order to indentify the question and answer that compose the same learning pill, the attribute condition has been used to indicate the learning pill name (ID cannot be used because it has to be unique in the document).

E. *Other features*

One of the materials that teachers provide to course students is a problem set. This type of material is very useful to students in order to prepare assignments and to learn practical part of the course. The problem set is composed by open questions that the teacher obtains from the learning material (assessment and learning pills).

The proposed DocBook markup for this type of content is simple: the remap attribute is used to indicate questions (or learning pill questions) that belong to the set using a special value (remap="question_set"). It is important to point out that the selected questions will compose a set of open response questions. So, the selected answer will have to maintain their meaning without including responses.

Another type of markup defined for learning material in the macro-document is the indication of appearance of certain content in the student lesson. This exclusion can be marked by the author because some part of the content can be intended only for the teacher, like comments and estimated time for explanations, assessment question for the final assignment and so on.

This markup has been defined using the attribute condition of the child elements of the current section or chapter. The value for this attribute is no_show (condition="no_show") in case the author do not want this element to appear in the student lesson. If this attribute has a value in the selected element, it is possible to indicate several values of this attribute separated by commas (i.e. condition="learnpill_example,no_show").

F. *DocBook markup summary and complete example*

As a summary of the previous defined markups has been defined in a table (see TABLE I.) for quick reference.

TABLE I. QICK REFERENCE MARKUP

Feature	**DocBook reference**	
	Meaning	***Markup***
objectives	Learning objectives attached to a chapter or section.	section/sectioninfo/ abstract/para role="objective"
cross-references	Identification of elements that can be referenced all across the document.	xref endterm="refered_ID" xi:include xpointer="path"
new question types	Definition of new question types.	qandaentry role="MCQ/MRQ/TF" ID="question_name"
hints	Hints attached to a question.	qandaentry/blockinfo /abstract/para role="hint"
duration	Duration of the question.	qandaentry/blockinfo /abstract/para role="duration"
incompatibility	Incompatibility between questions indication. This value can be multiple.	qandaentry/blockinfo /abstract/para role="incompat"
correctness	Correct response indication.	answer condition="correct"
learning pills	Learning pills definition.	role="learnpill_answer" role="learnpill_question" ID="learnpill_name"
not show	Content not showed to the student.	condition="no_show"
question set	Question set indication.	answer/learnpill_answer remap="question_set"

G. *XSLT processing and ADA integration*

As stated before, XSLT technology has been used for post-processing the macro-document. A series of templates (one for each learning material type) have been developed using XSLT. In this development, considered learning material types have been: units of learning (student lessons), assessments, learning pills and problem sets, so a XSLT for each of them has been developed. The process is detailed graphically in Figure 3.

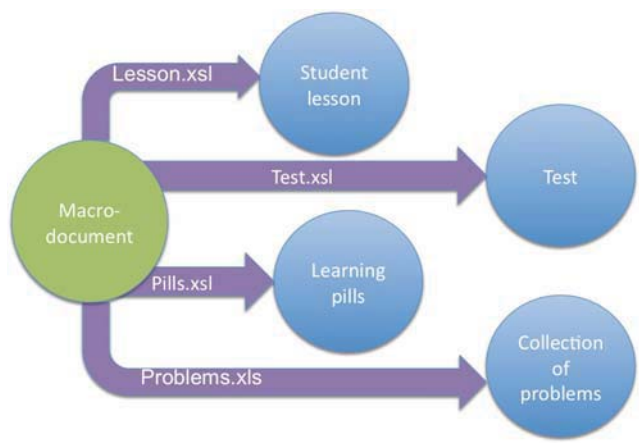

Figure 3. XSLT processing

Finally, integration in ADA production system has been achieved. A properties file (Properties.txt) is used in order to indicate the processing parameters used for the XSLT transformation. But in this case, the process of XSLT transformation has to be performed several times (one for each material type), what is not concerned by the tool. For solving this problem a module programmed using Apache Ant [16] has been developed specifically for macro-document processing.

H. Complete example

A chunk of a complete example of a macro-document is also provided in Figure 4. In this example, some of the explained features are shown. At section level a global learning objective is indicated using metadata markup (*sectioninfo/abstract*) and the attribute role with value *objective*. That exemplifies its simple usage for the material author. After that, some chunks of text have been marked with an ID (*phrase*, *programlisting*) so they can be referenced from anywhere in the document through *xref* tag and *xi:include* if some content should be included. This referencing is also exemplified in some *answers* of a *qandaset*. This same question is defined as a multiple choice question (MCQ). In the metadata of this question have been also included incompatible questions, duration and hints using the suitable roles. Finally, a learning pill answer is presented that reuses some text of the student lesson. Thus, flexibility and reusability features of the defined markup are shown.

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE section PUBLIC "-//OASIS//DTD DocBook XML V4.5//EN"
"http://www.oasis-open.org/docbook/xml/4.5/docbookx.dtd">
<section>
  <sectioninfo>
    <date>2009-08-21</date>

    <author>
      <firstname>Israel</firstname>

      <surname>Gutiérrez</surname>
    </author>

    <abstract>
      <para role="objective">Aprender los tipos de recursión lineal</para>
    </abstract>
  </sectioninfo>

  <title>Tipos de recursión lineal</title>

  <para>Un método recursivo lineal puede serlo por la cola o no por la
  cola.</para>

  <para>El siguiente método es <phrase id="no_cola_n" role="id">recursivo no
  por la cola</phrase>:
    <programlisting id="fac" role="id">
      long fac (int n){
        if(n&lt;=1) return 1;
        else return n*fac(n-1);
      }
    </programlisting>
  </para>
  <qandaset>
    <qandadiv>
      <qandaentry id="q_no_cola" role="mcq">
        <blockinfo>
          <abstract>
            <para role="incompat">q_cola</para>
            <para role="incompat">q_cola_no_cola</para>
            <para role="hint"><xref endterm="cola" linkend="cola" /></para>
            <para role="duration">1</para>
          </abstract>
        </blockinfo>

        <question remap="question_set">
          <para>¿De qué tipo es este método? <programlisting><xref
                endterm="fac" linkend="fac" /></programlisting></para>
        </question>

          <answer condition="correct">
            <para><xref endterm="no_cola_n" linkend="no_cola_n" /></para>
          </answer>

          <answer>
            <para><xref endterm="cola_n" linkend="cola_n" /></para>
          </answer>

          <answer>
            <para>En cascada</para>
          </answer>

          <answer>
            <para>Ninguna de las anteriores</para>
          </answer>
        </qandaentry>
      </qandadiv>
    </qandaset>

    <para condition="cola" role="learnpill_answer">El siguiente método es
    <phrase id="cola_n" role="id">recursivo por la cola </phrase>:
      <programlisting id="fact" role="id">
        long fact (int n,m){
          if(n&lt;=1) return m; else
          return fact(n-1,n*m);
        }
      </programlisting>
    </para>
```

Figure 4. Macro-document example

The macro-document processing is carried out in the production phase. An example of XSLT processing for learning pills extraction is presented id Figure 5. This piece of code searchs all entities in the macro-document that have the role of learnpill_question or learnpill_answer and put together the ones with the same learning pill name (using the attribute condition). Besides, it includes some DocBook code in order to create the output file with a defined syntax used in learning pills production.

```
<?xml version="1.0" encoding="UTF-8" ?>

<xsl:stylesheet version="1.0" xmlns:xsl="http://www.w3.org/1999/XSL/Transform">

    <xsl:output method="xml" indent="yes"/>

    <xsl:template match="/">
        <section condition="learnpills">
            <qandaset>
                <xsl:for-each select="//*[@role='learnpill_question']">
                <qandaentry>
                    <question class="question">
                    <title>
                        <phrase lang="es">¿SABÍAS QUE...?</phrase>
                        <phrase lang="en">¿DID YOU KNOW THAT...?</phrase>
                    </title>
                        <para lang="es">
                            <xsl:copy-of select="child::node()"/>
                        </para>
                    </question>
                    <answer>
                        <para lang="es">
                            <xsl:variable name="learnpillname" select="@condition" />
                            <xsl:for-each select="//*[@role='learnpill_answer']">
                                <xsl:if test="//*[@condition=$learnpillname]">
                                    <xsl:copy-of select="child::node()"/>
                                </xsl:if>
                            </xsl:for-each>
                        </para>
                    </answer>
                </qandaentry>
                </xsl:for-each>
            </qandaset>
        </section>
    </xsl:template>

</xsl:stylesheet>
```

Figure 5. XSLT example for learning pills

The output file obtained after the XSLT processing is shown in Figure 6. This output is a DocBook format document used for learning pills declaration. After a usual DocBook processing it can be converted in the final HTML final that shows the learning pills deck, like the one shown in Figure 2.

```xml
<?xml version="1.0" encoding="utf-8"?>
<section condition="learnpills">
  <qandaset>
    <qandaentry>
      <question class="question">
        <title>
          <phrase lang="es">¿SABÍAS QUE...?</phrase>
          <phrase lang="en">¿DID YOU KNOW THAT...?</phrase>
        </title>
        <para lang="es">En un método recursivo por la cola, en cada rama
            del condicional la última operación (la más externa) que se ejecuta
            es la llamada recursiva.</para>
      </question>
      <answer>
        <para lang="es">El siguiente método es
          <phrase id="cola_n" role="id">recursivo por la cola</phrase>:
          <phrase id="fact" role="id">
            <programlisting>
              long fact (int n,m){
                if(n&lt;=1) return m; else
                return fact(n-1,n*m);
              }
            </programlisting>
          </phrase>
        </para>
      </answer>
    </qandaentry>
  </qandaset>
</section>
```

Figure 6. Learning pills output document

IV. Conclusions and Future Work

A markup using DocBook has been defined in order to solve the main problems of material authors: material variety and continuous update. The solution developed also includes tools for learning outcomes and objectives management and evidences automatic generation.

In order to test the validity of this development it has been integrated into the tool of material production ADA. In the near future it will be used to create material for some subjects in the Carlos III University in the second semester of the current course (2009-2010).

As future works for this development, the learning outcomes management is in a very preliminary stage because it is only defined at section level (learning objectives). The learning outcomes management definition at course level will be the next step. Besides, the automatic creation of evidences as a proof of the section objectives and then the course level learning outcomes. In this way, it would be necessary the introduction of new types of assessment types like practice seasons or simulations. It would be also a great feature the possibility of creating adaptive questions using hints.

Finally, an evolution of the markup is proposed in order to define high-level concepts and to automate more widely the creation of material. This markup should be defined out of the DocBook schema and should be composed by high-level concepts like definition, concept, taxonomy, etc. In this way, some material like assessments or learning pills can be automated.

Acknowledgment

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Session 02C Area 2: Innovative Engineering Courses and Labs - Laboratories

Developing an Optical Spectrum Analyzer
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A new Systemic Methodology for Lab Learning based on a Cooperative Learning Project
Barrero, Federico; Cortés, Francisco; Gutiérrez-Reina, Daniel; Hinojo, José María; Toral-Marín, Sergio L
University of Seville (Spain)

An Experience of a Multidisciplinary Activity in a Biomedical Engineering Master Degree
Colomer-Farrarons, Jordi; Miribel-Català, Pere
University of Barcelona (Spain)

An Undergraduate Microwave and RF Low-Profile Laboratory
Fernández-Pantoja, Mario; García-Ruiz, Francisco; González-García, Salvador; Rodríguez-Santiago, Noel
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Developing an Optical Spectrum Analyzer

Realizing a complex embedded system with student groups

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Abstract— **Within the curriculum of the Bachelor Electrical Engineering there are obligatory lab experiments for electrical measurement. In this lab ready-made standard experiments with defined results are carried out by students. As an alternative to these standard experiments individual development projects for interested students are offered. In one series of projects an Optical Spectrum Analyzer (OSA) is going to be realized by students. The complete opto-mechanical hardware was sponsored by a measurement company and groups of students develop additional components to complete the OSA. Currently all important electronic subsystems of the OSA are developed and tested. These are integrated into the whole system and a software environment for controlling the whole system is built. The high learning success of the student groups and the consistently positive feedback from the students is encouraging. Currently this type of project is expanded to other topics.**

Analog circuits; Educational technology; Electronics engineering education; Optical spectroscopy

I. Introduction

In the study course Bachelor of Electrical Engineering there are the lectures Electrical Measurement part 1 (in the second semester) and part 2 (in the fourth semester) with the laboratory courses Electrical Measurement part 1 (in the third semester) and part 2 (in the fourth semester) where groups of usually three to four students carry out experiments for gaining practical experience in electrical measurement and analog electronics. During the lab course 1 some basic skills like handling measurement instruments and doing elementary experiments are taught. In the second lab course more advanced experiments are done to increase the practical electric measurement skills of the students.

Some years ago skilled and motivated students asked for projects instead of the standard lab experiments to gain industry relevant experience. Due to this demand the project "OSA development" was created where student groups develop a new electronic and software environment around an existing opto-mechanical OSA hardware block. This project takes a whole semester with an estimated work load of about 30-40 hours for each student. These projects are voluntary instead of the standard lab experiments. This leads to a high intrinsic motivation of the student groups [1].

The opto-mechanical hardware for the Optical Spectrum Analyzer and a laser source were sponsored by JDSU. The I/O-Board for connecting the OSA to a PC was sponsored by National Instruments.

II. Scope of Project

In the German Universities of Applied Science the education of engineers connects theoretical knowledge with industry relevant practical experience. In Industry most projects contain theoretical and practical parts which are carried out within a team. A technical framework is already given before the start of the project and new parts or functions which interact with the framework have to be developed.

Here the students train this industry relevant type of project and get practical engineering skills which are essential for their professional life. They see the difference between theoretical knowledge and practical work. For many of the students it is their first practical hardware development within a team and they learn how to divide a project into different work packages, carry them out and combine them to a complex device.

The technical basis for this professional training is the development of a working OSA which has challenging electronic building blocks. The goal is to finish an OSA with working hard- and software to use it for lab education.

III. Project Organization and Phases

After the student group received their project specification and an introduction lesson into the functionality of an Optical Spectrum Analyzer the group is requested to organize the project by itself. The adviser of the lab course gives hints if technical problems arise which cannot be solved by the group alone. If problems between the students arise mediation can also be required.

The project scheme is usually chosen by the students as follows:

- They start to become familiar with the tasks and with the given hardware.
- The students separate the project into parts and distribute the tasks among the team members.
- They develop electronic circuits, calculate and simulate the performance. With feedback from the adviser they optimize the performance of the circuit.
- The students look for appropriate electronic parts at the manufacturers' web sites and order samples.

- With these parts they build a first test circuit and verify the correct operation. Problems are found and fixed and sometimes the circuit is further optimized.
- From the experience of the first circuit the students draw a layout for an etched printed circuit board (PCB). It is made, assembled and tested. The parameters are measured and compared with theory.
- After the hardware works the students have to present their results to the other lab groups. They usually prepare a PowerPoint presentation where the highlights of the project are depicted.

During the whole project the students must document the project work and their results. This documentation is stored as a basis for following project groups.

IV. Given Opto-Mechanical Hardware

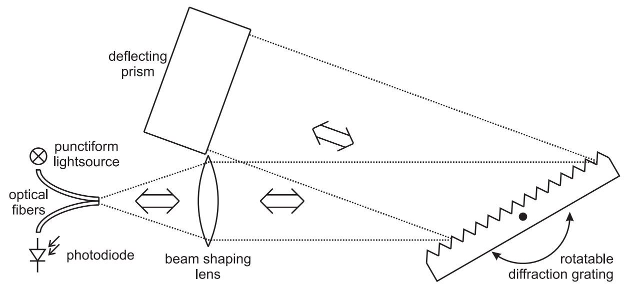

Figure 1. Optical setup of OSA

The given opto-mechanical hardware is from a JDSU OSA-201 [2][3]. The principle of the optical setup is shown in figure 1. It is a single monochromator in littman configuration where the diffraction grating is passed twice for high spectral resolution. The grating is rotated using a scanner motor with flexure bearings. Light is coupled via single mode fibers into the OSA. At the output side photodiodes convert the optical output power into a proportional electric current. A wavelength reference (which is not shown in fig. 1) with an infrared light emitting diode (LED) and an acetylene gas cell is integrated which can be used for wavelength calibration during operation. The wavelength range of the OSA is from 1250nm to 1650nm which is limited by the maximum angle of the scanner motor. Figure 2 shows a photo of the opto-mechanical hardware.

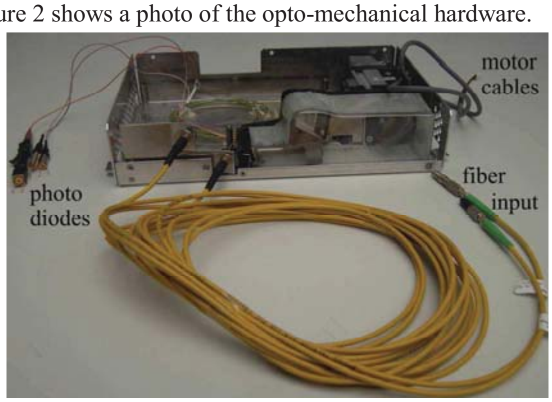

Figure 2. Opto-mechanical hardware of OSA

V. Reached Project Status

Up to now the main building blocks of the OSA electronics are developed and tested. The system is integrated and a first version of the control software is written. The following projects of the OSA development are realized:

A. *Summer semester 2008*

1) *Linear transimpedance amplifier*

This was the first test project to see if the new concept for the electrical measurement lab works. One group of two students had to build a linear transimpedance amplifier to convert the photodiode current into a proportional voltage. After designing the electronics and selecting the components they soldered a test circuit on a grid-style PCB and verified the correct function. In a second iteration they made a layout, fabricated an etched PCB and tested the correct function of the circuit. In the third iteration they added a low pass filter for improved noise performance, fabricated a new PCB and documented the results. In figure 3 the last version of the transimpedance amplifier is shown. The left operational amplifier converts the photodiode current coming through the red cable into a voltage. With the right operational amplifier an active low pass filter is realized.

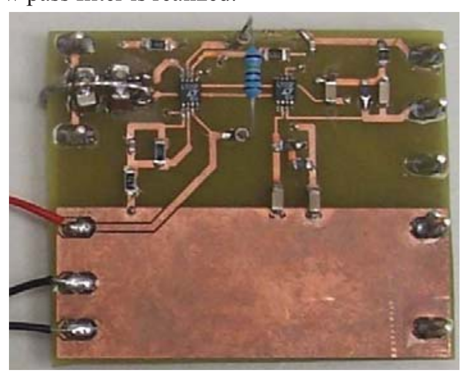

Figure 3. PCB circuit of linear transimpedance amplifier

B. *Winter semester 2008/09*

1) *Logarithmic transimpedance amplifier*

The logarithmic transimpedance amplifier converts the photo diode current into a logarithmic voltage. This has two advantages compared with a linear amplifier. First the current range of many decades is measurable with one amplifier and second the output voltage can be directly displayed in a logarithmic scale which is usual for optical telecommunication applications.

A group of four students developed this project. They first became familiar with the theory of the concept and then calculated the properties of the circuit. A rail to rail operational amplifier with low noise was selected from a vendor's homepage and the calculated circuit was simulated. After drawing a layout, building a PCB and assembling the parts they measured the response curve of the amplifier (fig. 4). The photo current is on the logarithmic abscissa and the output voltage is on the ordinate. The circuit shows a good logarithmic behavior which is in line with theory.

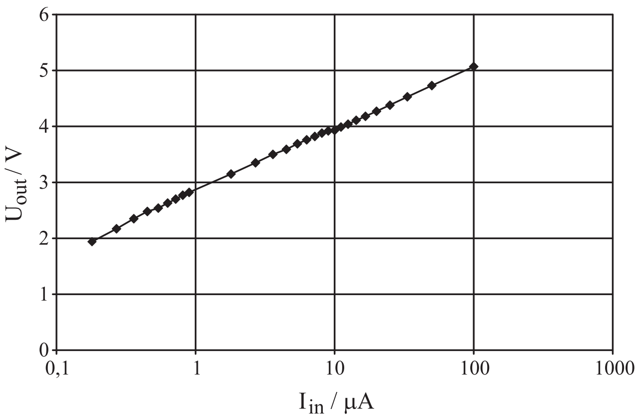

Figure 4. Response curve of logarithmic transimpedance amplifier

2) Motor driver using a microcontroller

One group had the task to develop a drive electronic for the motor. The intention from the supervisor was the development of a linear driver with an H-bridge. This was not clearly enough communicated to the student group so they decided to use a microcontroller and switching transistors for powering the motor. The controller was programmed with a constant velocity ramp and depending on the motor position the pulse width of the switch transistors was changed. This project succeeded but it was not possible to integrate this circuit into the system. Therefore it was decided to repeat this development during the next semester with more precise specifications.

3) Driver electronics for wavelength reference LED

The infrared LED for wavelength referencing must be supplied with a constant current. This current is controlled using an integrated monitor photodiode which detects the output power of the LED. A current source was developed by the student group which supplies a constant current independent of the LED and environmental conditions. A test board was developed using a blue LED where the functions can directly be seen. A current limiter with a limit of 200mA was implemented to protect the LED from destruction. A PCB with the final circuit was built and verified.

C. Summer semester 2009

1) Angle sensor electronics

In the scanner motor a capacitive angle sensor is integrated. This sensor is driven by an external DC-voltage and outputs two currents with the angle proportional to the difference of these currents. A group of four students realized this demanding project with their main scope on a low noise circuit. After learning the noise theory, designing the circuit and selecting the components they calculated the amplifier noise. They saw that this was much lower than the noise from the position sensor and so they built up this amplifier.

Figure 5 shows the block diagram of the angle sensor. The output currents of the angle sensor are transformed into voltages by transimpedance amplifiers. These values are added and the sum acts as a control input for the angle sensor supply. The current difference is the output signal of the sensor electronics and proportional to the scanner drive angle.

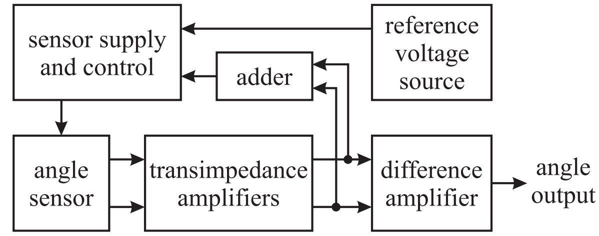

Figure 5. Block diagram of position sensor

2) Linear motor driver using an H-bridge

The project for building a motor driver electronic was again offered. In the tighter project specifications an analog input voltage with a proportional output voltage was demanded. The student group chose an operational pre-amplifier which transforms the range of the input voltage to an appropriate voltage for the bipolar H-bridge transistors. With a feedback loop from the output of the H-bridge to the input of the pre-amplifier the distortions around the zero voltage output of the H-bridge are compensated.

Together with the student group developing the angle sensor they built up a test set up with a scanner drive and their electronics to show the function of the whole motor drive and position sensor system.

D. Winter semester 2009/10

1) Connecting the hardware parts and creating a control software using LABVIEW

The opto-mechanical OSA hardware was connected to the motor driver, the position sensor and the logarithmic transimpedance amplifier. These parts were connected to a PC using an interface card with analog/digital and digital/analog converters. The student group used LABVIEW to set the driving voltage for the motor and read out the voltage of the logarithmic transimpedance amplifier. By stepping the motor voltage over the whole range while reading out the amplifier values an uncalibrated optical spectrum was constructed and shown on the screen. Two fabry-perot laser diodes with 1310nm and 1550nm wavelengths were coupled into the OSA input fiber. Figure 6 shows this first measured spectrum with the two lasers in it.

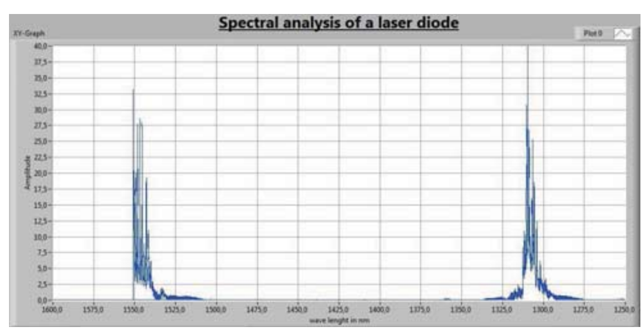

Figure 6. First measured spectrum with OSA

VI. Feedback from Students

After each project completion systematic feedback from all students was gathered. Here the main points which were highlighted by the students:

- Summer semester 2008, transimpedance amplifier: The project was very interesting because of the different tasks. It was very good to see the results and the success. A better explanation should be made how parts are sampled and PCBs are ordered. At the beginning the work load and the division of the project among the students were unclear.
- Winter semester 2008/09, LED driver: It is better than lab courses with fixed experiments because of a higher motivation, learning from own mistakes, having a free time schedule.
- Winter semester 2008/09, motor driver: The learning effect was very high but the project was also very time-consuming. The group work was a lot of fun. It was better than the standard lab experiments.
- Winter semester 2008/09, transimpedance amplifier: Positive was the own development of an electronic circuit, independent work made fun. The main disadvantage was the high work load.
- Summer semester 2009, position sensor: The advantages were the free time schedule and the creative work. The project matched with the theoretical lectures during the fourth semester. The project was an instructional experience and a good alternative the normal lab course.
- Summer semester 2009, motor driver: The expenditure of time was higher than expected. The development of the electronic circuit was challenging but funny.

VII. Conclusion

From advisers' side we saw that during these projects the students got a higher knowledge increase than with the prepared standard experiments. This was also confirmed by the written test at the end of the lab course. The grades of the project students were better than the average course value.

The students already had a lecture of analog electronics but for many them this project was the first practical experience with the design and assembly of an electronic circuit. At the start of the project many students had great difficulties to transfer the theoretical knowledge into practice. During the project they learned how to build a working electronic board with all practical problems.

The groups had to organize itself. They divided the individual tasks among the project members and combined the parts to one solution. At the beginning this was challenging because no adviser gave them a detailed instruction how to schedule the work. During the project the students formed a team where one could rely on the others.

At the end of the project the students had to present the work results in front of the advisers and the other students. This was a challenge for the introverted ones but in professional life it is inevitable to present the work in an appropriate way.

We also saw some risks during the projects. The way how to solve the project was open, so some groups found impractical or wrong solutions. If the students came during the project work to a dead end they spent a lot of time without finding the further way. The consultation of the adviser was very late so the groups lost a lot of time or presented an unrealistic solution. It is important from the advisers' side to clearly tell that consultation and discussion does not lead to grade degradation. It is also important to ask for one or two interim reports to see how the project is going on and how much time is already spent.

During the first semesters the project specifications were short to give the students maximum freedom for developing own solutions. This was considered negative from some groups because students were uncertain which technical solution they should choose. Therefore in the last semesters the specifications were detailed and the problem disappeared.

VIII. Planned Work and Outlook

After the winter semester 2009/10 semester we have finished the first version of a working OSA system. During the next projects two main work directions are planned.

During integrating the OSA some problems with the actual transimpedance amplifiers arose concerning speed and value range. Therefore it is planned to build new amplifiers with improved characteristics. The second goal is the improvement of the measurement algorithms with filtering the position and optical power values. A wavelength calibration algorithm should be implemented and tested. It would be very interesting to calibrate the self-built OSA and compare it to a commercial one.

Due to the high success of this type of project we offer in the meantime other topics. Additionally we started the work on a wireless weather station which is modularly set up and therefore expandable to any functional range.

In the middle future we intend to switch the whole lab course from fixed experiments to project work to provide an optimal education for our engineers.

Acknowledgments

First of all I want to thank all the highly motivated and competent students who carried out the project work. They made this new type of lab experiments a success. I also thank my colleagues for the fruitful discussions when creating and optimizing this type of project work.

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A new Systemic Methodology for Lab Learning based on a Cooperative Learning Project

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Abstract—**The idea of this paper consists of developing a new methodology based on a complex system that will be analyzed and programmed by several groups of students that must work openly and cooperatively to achieve a final global result. For this purpose, a personal digital assistant developed as an open hardware called OpenMoko has been selected. The paper details the experience of working with this system and highlights the main obtained benefits.**

Keywords-systemic methodology; cooperative projects; open hardware; lab learning;

I. SUMMARY

Cooperative learning (CL) is a successful teaching strategy based on the constructivist theory of learning in which small teams, each with students of different levels of ability, use a variety of learning activities to improve their understanding of a subject [1], [2]. Usually, learners are divided into different groups so that they can discuss and share their work with each other during the learning process to increase the efficiency and quality of their learning. One of the main benefits of cooperative learning is that learners can improve their ability in the subject and learn to adjust their interpersonal relationships through interactions with other group members [3]. In cooperative learning situations there is a positive interdependence among students' goal attainments; students perceive that they can reach their learning goals if and only if the other students in the learning group also reach their goals [4]. Cooperative learning must be distinguished from group work. Although cooperative learning does employ groups (actually teams), group work is not necessarily cooperative learning. The main differences of Cooperative Learning (CL) respect to small-group discussions and group projects typically used in Higher Education are the selection of group members on the basis of predetermined criteria which have been deliberately designed to potentiate the positive effects of small group learning, the continuity of group interaction, the interdependence among group members, the explicit attention to the development of social skills, and the role of instructor as a facilitator [5].

On the other hand, project based learning (PBL) is an educational teaching and learning methodology that has been actively used for some time now. Project-based learning is grounded in general theories of knowledge such as situated learning [6], which states that knowledge must be presented in an authentic context, using settings and applications that would normally involve that knowledge, and includes social interaction and collaboration to solve complex problems [7], [8]. When compared to traditional lecture-based or teacher-centered engineering curriculum, the PBL model appears to inspire a higher degree of involvement in study activity [9]. In this case, PBL should not be confused with problem-based learning. The main difference is that in project-based learning, students mainly apply previously acquired knowledge and the production of some final product is the central focus of the assignment. By contrast, problem-based learning students have not previously received formal instruction in the necessary background material and the solution process is more important than the final product [10], [11].

This paper proposes the combination of both concepts in an electronic lab subject using a complex system over which groups of students can develop partial works. An open hardware project called OpenMoko has been chosen as the complex system in which both learning strategies are developed. Openmoko™ is a project dedicated to delivering mobile phones with an open source software stack. The Openmoko stack, which includes a full X server, allows users and developers to transform mobile hardware platforms into unique products. The license under which is released gives developers and users freedom to cosmetically customize their device or radically remix it.

II. METHODOLOGY DESCRIPTION

The proposed project consists of building an application for an Openmoko phone able to connect to a beacon (implemented in a PC) which provides information pages through a Bluetooth link. These pages are very simple and can contain texts, menus and sounds. Due to the complexity of the project, four subgroups were created:

- Subgroup 1: Bluetooth. The objective of this subproject consists of managing a Bluetooth link between OpenMoko and the Pc beacon.
- Subgroup 2: Graphic Interface (QT). This subproject consists of working with the QT framework to develop a graphic interface.

- Subgroup 3: Audio Interface. Mplayer software is used to play both local files as well as the audio information transmitted by the beacon.
- Subgroup 4: Accelerometer. The embedded accelerometer is used to recognize some movements and perform some actions depending on the detected movements.

The global project is specified in detail. Consequently, each subproject must develop its own tasks but taking into account the activities and interfaces with the rest of subprojects working with the OpenMoko system.

In the first few sessions the teacher explains some introductory lessons about the GNU/Linux operating system, the Openmoko platform and the development tools. In order to facilitate the work both inside and outside the classroom, the teacher created an image of a GNU/Linux distribution with the toolchain installed so that the students could use it by simply installing an open source virtualization platform. In this way students can work in their own PCs with the same environment without having to change their O.S. or spend time installing the toolchain and setting up the environment.

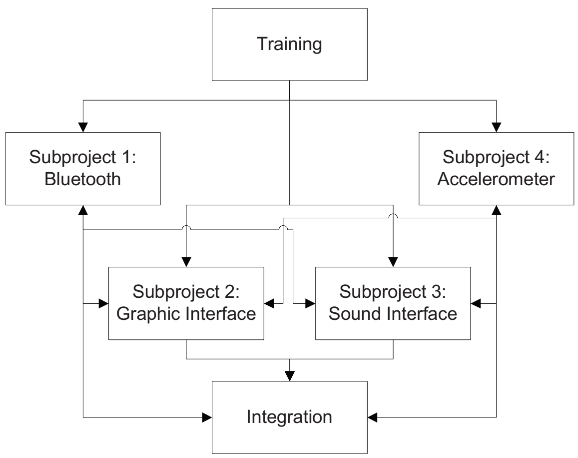

Figure 1. Stages of the methodology and subprojects relationships.

The following sessions were dedicated to the project's development and they were divided in three stages, Figure 1:

- Stage 1: Training. In this stage students must study the technologies and tools related with their subproject, and they must perform small test programs.
- Stage 2: Modular design and specifications. First, the particular specifications of each subprojects are defined, working in a coordinated manner with the rest of groups. Necessities are analyzed and specifications are agreed to guarantee the compatibility of the modular developments performed by each group. Second, each individual project is launched and developed.
- Stage 3: Integration. All the individual projects are joined together, making the necessary corrections to achieve the required main functionality.

During the development of individual subprojects, the first minutes of each class were devoted to follow-up reviews. Then, the self-learning of the group and the utilization of previous knowledge and skills of each group member are promoted.

III. RESULTS

The obtained results by each subgroup are next detailed:

Subgroup 1: Bluetooth. The students managed to establish a connection between the Openmoko phone and a computer by using Bluetooth's SDP profile and RFCOMM protocol. The SDP profile was used to publish the specific service so that the devices belonging to the system can connect between them without bothering devices that do not belong to the system. For the data transfers, the students used the RFCOMM protocol, since it provides a serial-like link. They also designed a specific application layer protocol intended to be run on top of RFCOMM, Figure 2. This way they can send easily simple files describing the data that should be displayed on the Openmoko terminal.

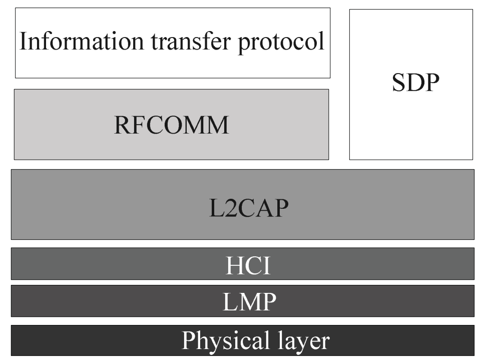

Figure 2. Protocols of the Bluetooth link.

Subgroup 2: Graphic interface. The progress of this task was slower than others due to some problems the students had to face, but finally they managed to build simple windows on demand, at runtime, using QT as the framework for developing the graphic user interface.

Figure 3. Graphic interface.

Subgroup 3: Audio interface. This subgroup built a basic sound infrastructure based on mplayer that was able to play both local files and streams. This infrastructure is intended to be used together with the Bluetooth module in order to play the incoming streams from the beacon (PC).

The designed sound interface uses the sound infrastructure and certain audio applications that are installed in OpenMoko phones, adapting them to fit our application requirements. These needs are focused basically on playing OGG/Vorbis compressed audio streams which are received through the Bluetooth connection. The group assigned to this subproject managed to create programs that played audio streams by using ALSA and Mplayer. In order to accomplish this, they launched Mplayer in command mode and created a pair of pipes (FIFOs), one for sending the audio stream and the other one for sending commands. The sound interface is able to launch on demand several Mplayer instances running in background simultaneously. They also made some tests to integrate a text-to-speech program (Festival) within the sound interface and managed to generate little audio chunks and compress them in OGG/Vorbis format. This group even defined the API functions necessary to control the interface. They implemented these API functions as a library (libsui.a) which can be linked to any application using the sound interface. The set of functions that control the audio player were implemented as an independent program running in background (suid),, Figure 4.

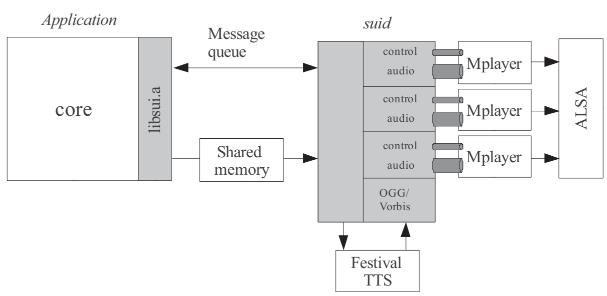

Figure 4. Audio interface scheme.

Subgroup 4: Accelerometer. The students managed to retrieve the accelerometer's data and do a simple post-processing on the data to detect certain movements. In the third stage this events are reported to the main application. This way, the user could change the selected item in a menu by simply moving the phone.

Integration. The previous subprojects have been integrated in a final application where the human machine interface is solved making use of hand movements. Whenever the phone is moved up-down-left-right, the cursor is accordingly moved. This way the final user can visualize incoming information or play incoming audio streaming. The integration stage requires the different subgroups must negotiate common interface specifications.

IV. PEDAGOGICAL EVALUATION AND BENEFITS

To analyze the pedagogical value of the proposed lab learning methodology, we must first corroborate that we are indeed developing the mentioned cooperative and project based learning.

The key pedagogical assumptions of cooperative learning are: (i) knowledge is created as it is shared. Therefore the more students share information the more they learn; (ii) that learner’s have prior knowledge they can contribute to the discussion; (iii) that participation is critical to learning and; (iv) that learners will participate if given optimal conditions [12], [13]. To accomplish these premises, groups must work together and members should solve problems by a process of discussion and interpretation of results. Participation is encouraged because groups should evaluate themselves at the end of the course indicating the degree of involvement of each member. Participation is one of the main antecedents of information sharing [14][15], and knowledge sharing allows the creation of new knowledge through a process of knowledge revealing, knowledge reusing and knowledge recombination. The use of prior knowledge is also promoted with an intentional group formation. Groups are formed trying to merge different students’ profiles in terms of previous knowledge and previous curriculum. Finally, students have available all the technical resources, including documentation, lab equipments, and the complete framework for working with OpenMoko

On the other hand, PBL has also several premised that should be accomplished. Some authors [11], [16] takes a broader approach to defining PBL, offering five criteria that a class project must have in order to be considered an instance of project-based learning. The project must be (a) central to the curriculum, (b) focused on questions or problems that drive learners to encounter and struggle with the central concepts and principles of a discipline, (c) a constructive investigation or goal-directed process that involves inquiry, knowledge building and resolution, (d) conducive to student autonomy, choice, unsupervised work time, and (e) realistic, focusing on authentic challenges where the solutions have the potential to be implemented. All these premises are also considered in the proposed methodology. OpenMoko is an open hardware intended to perform developments directly related with a lab learning activity. The course organization also pursuits a constructive approach, promoting the discussion, the searching of solutions and alternatives, and improving the students autonomy when facing a new and unknown problem. Finally, the integration stage guarantees the result is realistic because it is finally implemented.

The main benefits of CL have been highlighted in [17], where they analyze 120 studies to compare the relative advantages of cooperative, competitive, and individualistic learning on individual achievement. The results show that cooperative learning promoted greater achievement than competitive or individualistic learning methods. The research also found that cooperation promoted greater intrinsic motivation to learn, more frequent use of cognitive processes such as re-conceptualization, higher-level reasoning, meta-cognition, cognitive elaboration, and networking, and greater long-term maintenance of the skills learned. At the end of the course, it was checked that students' motivation was improved. They exhibit a high degree of involvement if their tasks. In particular, the integration stage was valued as the most exciting and interesting phase of the project development.

The main benefits of project based learning are listed below:

- Students develop skills and competences like collaboration, project planning, decision taking, communication and time management.
- The learning process is linked with real life, and this issue contributes to improve knowledge and skills as students are more involved with the project.
- Development of collaborations skills to build new knowledge. Student must share ideas, and then discuss and negotiate solutions.

The work with OpenMoko is clearly linked with the field of mobile phones applications. The use of Bluetooth and accelerometers are linked with emergent technologies and students feel strongly motivated for this kind of tasks. The course organization as subprojects integrated in a global big project makes necessary not only the collaboration between group member but also the discussions and negotiations between groups themselves.

V. CONCLUSIONS

This main novelty of this paper is the integration of cooperative and project based learning in an open platform like OpenMoko. The course has been designed to consider both learning methodologies and to take advantages of their benefits. The obtained feedback signals the integration stage and the link with real life as the most interesting issues covered by this course.

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An Experience of a Multidisciplinary Activity in a Biomedical Engineering Master Degree

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Abstract- **Training Biomedical Engineers presents major challenges because of the different backgrounds they are coming from. These activities should stimulate the student's professional skills and, in the particular case of a Master Degree, this is even more complicated. It represents a higher educational level where students should increase and improve their ability to solve problems related to very different areas such as the engineering and biomedical. The Biomedical Master Degree shared between the *Universitat Politecnica de Catalunya* and the *Universitat de Barcelona* has students coming with extremely different backgrounds, from the medical or biological to the engineering profile. Taking into account this situation, we have developed a *4-days multidisciplinary charge activity* in a particular course of Biomedical Devices. It is focused on the amperometric sensors and in the conception and application of biopotentiostat amplifiers. Regardless the student's profile the activity is focused in such a way that everyone has to work actively in the experience. This paper presents a proposal based on co-operative learning strategy and the feedback that students give to the learning process as a first approach for future improvements.**

Index terms: Biomedical Engineering Education, Workgroup teaching, Analog electronics teaching.

I. Introduction

The Bologna process in the European Union (EU) has been defining, since 1999, a new conception of the Credit measurement [1-3]. This European treaty that should be concluded in 2010 is the configuration of the European Higher Education Area. It brought a reformation in all the European Countries involved, in order to establish qualification comparability criteria for all the higher education institutions in Europe.

This new credit, defined by the European Credit Transfer System (ECTS) must be a measurement of the full student's work [4-6]. This conception imposes a more practical approach in the learning process, and it is of particular interest in technological disciplines where technical practices are essential for a complete learning. This was one of the main reasons to develop this activity, as a different approach to classical laboratory experiences. In the case of a Master degree in Biomedical Engineering, in the University of Barcelona [7], is even more important taking into account that the profile of the students covers several areas, and the conception of the curricular courses is a key point for their professional's future.

This Master degree is conceived with 120 ECTS credits which are distributed in 4 semesters.

As it was mentioned before, due to that this Master degree is cursed by students of different degrees, like Biology, Biochemistry, Pharmacy, Medicine, Veterinary, Ontology, Electrical, Electronics, Mechanical, Biomedical Engineering, Physics, and Chemistry, the students should follow different schedules depending on their previous knowledge. Students coming from Biological and/or Biomedical area can just overcome 60 credits to obtain their master degree. On the other hand, students coming with engineering, physics, and chemistry backgrounds must complete 5 ECTS extra credits.

In this paper is presented the conception of a specific experience in the course of Biomedical Devices, designed to an optional subject in the curricular formation of the students.

II. Background and Interest of the Activity.

The particular problem we have encountered has been how design an activity that allows students with different profiles work together ***actively*** in the lab, and an initial cooperative work has been followed. Interesting approaches have been presented in [8-9].

The key aspect is the design of one activity that allows to put to work in the same laboratory students as heterogeneous as we have found, being a completely new experience for teachers and also for students.

For this course, the theory is designed to cover several topics to understand, design and work with basic biomedical devices. Firstly, there is an introduction to the measurement systems, focused on devices and instrumentation for measurements of temperature, pressure and flow. Also there is a basic explanation of different types of sensors and biosensors such calorimetric, potentiometric, amperometric, optical biosensors, immunosensors and bio-optoelectronics, and to finish the students learn concepts of Electrochemical techniques, like voltammetry and Electrochemical Impedance Spectroscopy [11-13].

In particular, in the field of sensors and biosensors, the introduction to the concept of Potentiostat Amplifiers, and their applications with biosensors, has been used to design such activity for students that either have an electrical engineering profile or for those who are coming from other areas and could have a weak background in electronics.

Different objectives are pursued in the design of the experience. One is the development of an integrative laboratory that promotes inquiry, relevance, and hands-on experience for students with different profiles [14]. We do not want groups where just only some students work actively in the lab, depending on the type of activity. The scope of the activity is that everyone work and participate actively. In this experience the students must applied their skills in math, science and engineering. The key aspects of the ABET EC 2000 criteria have been followed [15]. The students take measurements and interpret their results.

This experience is based on a traditional master class, but it is just one more element in the process. Thanks to the activities in the classroom and the laboratory, some other aspects are reinforced, like the communication and team work between the students, working in a multidisciplinary team, and a more hands-on approach to learning is developed [16-18].

An important aspect is the cost of the laboratories for the biomedical engineering education. The Biomedical Devices lab is organized in teams of two or three students, in ten full equipped tables with standard instrumentation equipment. In our case, a portable low-cost potentiostat amplifier has been designed for each table. In the classroom some commercial biopotentiostat amplifiers are presented, from different commercial suppliers, like a high performance amplifier from TekNet Electronics [19], or an educational potentiostat like the Voltalab 06 [20]. These equipments are quite expensive to be placed at each table. Through the designed equipment students have an approach to this type of equipments at a low cost for the University. These kinds of equipments are compared with our discrete amplifier at the end of the sessions. The discussion arises in terms of the trade-off between their performances and cost, where the commercial ones are much more expensive than our low-cost PCB design, (30 USA$ vs. more than 3000 USA$ for each commercial device and worktable). Following these approach we can also incorporate in our laboratory an experience to provide students with hands-on, real-world application.

The presented activity, that is centered in a cyclic voltammetry, is designed in order to work different aspects related to the students activities (ECTS credit transfer), and to work specific objectives in the course, which are the interest to present the feasibility to carry out electrochemical experiments controlled by a PC, and make noticeable how works the instrumentation used to interface the electronics with the experience.

III. DESIGN OF THE ACTIVITY

The activity is focused on the presentation of the potentiostat amplifier and its use to control a cyclic voltammetry. There are different techniques to define a Cyclic voltammetry [21-23]. In our case, it is an electrochemical technique based on a triangular scan of the potential of the working electrode. As the potential of the working electrode is scanned in one direction, any electroactive species in the sample will undergo reduction or oxidation (depending on the direction of the scan). As soon as the direction of the potential scan is reversed, the species will undergo the opposite reaction (oxidation or reduction, respectively). These electrochemical reactions give rise to redox currents, which are recorded as a function of potential. The current-potential graph is the cyclic voltammogram, which gives quantitative and qualitative chemical information.

The selected biopotentiostat setup uses a three electrodes sensors configuration [24-26] which are a) the working electrode (WE), which serves as a surface on where the electrochemical reaction takes place; b) the reference electrode (RE), used to measure the potential at the WE, and c) the counter electrode (CE), which supplies the needed current required for the electrochemical reaction at the WE.This amplifier controls the voltage between the WE and RE electrodes to a control input voltage (Vin). In order to keep this condition the current at the RE electrode should be ideally zero and no current should flow through it.

The potentiostat amplifier design has a very low-cost structure which is depicted in Fig.1. This structure is based on four operational amplifiers (Opamp) and two resistors. OP4 is the transimpedance amplifier, which defines the virtual ground voltage of the WE electrode and provides current-to-voltage conversion. The key characteristics of the transimpedance amplifier, in terms of its input impedance, very low input leakage current and offset voltage, are some of the elements that the students must work in the activity, working their thinking critical skills**.** The gain in theI/V conversion is defined by an external resistor. OP3 is used to ensure minimal current flows through the RE electrode. It senses the voltage difference between the RE and WE electrodes, that is measured between the RE voltage and the virtual ground. This difference is used by OP2 and compares this voltage with the desired Vin voltage, changing the voltage at the CE electrode and defining a current trough the cell in such a way that the voltage difference between the RE and WE electrodes follows the defined Vin signal that polarizes the sensitive cell.

The activity is divided into four different parts, which are programmed in two weeks, as is represented in Fig.2, where are also indicated the inputs for the student's evaluation. The total work for the students is estimated to be around 10h, which are equivalent to 5/6 ECTS, for this activity. Five of these hours represent practical work done by the students in the faculty, and the remainder of the hours represents their individual or group work out of the classroom and the laboratory. It is important to emphasize that the students can contact their supervisors/teachers by e-mail for tutorship if needed.

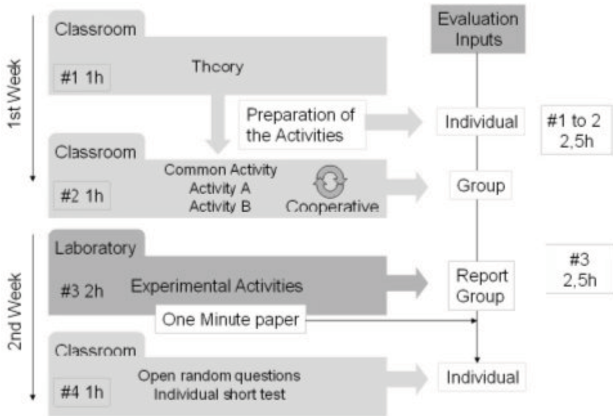


Fig.2: Schedule of the activities.

Team groups are formed by two classmates at least, where both are coming from different study areas but at least one of them should have engineering background. Ideally, a team of three members is preferred.

A work in the classroom is planned to present the circuit and experience, which is the first part of the program. The concepts of the potentiostat amplifier and the sensor are introduced in this section. The second class is devoted to a *cooperative task*.

In order to develop the work in the lab the students must prepare a theoretical previous work, which is developed here. This work is focused into three main activities, as a previous lab work, which programmed in terms of the student's profile.

This common activity for all the students is divided in two categories A and B. Activity A is oriented to students with an engineering background (A Student), and Activity B for the rest of them (B Student).

These activities must be read and prepared by the students before the class time. The common activity is based on the visual analysis and identification of the components used in the design of the potentiostat amplifier, of the designed PCB, which is depicted in Fig.3.

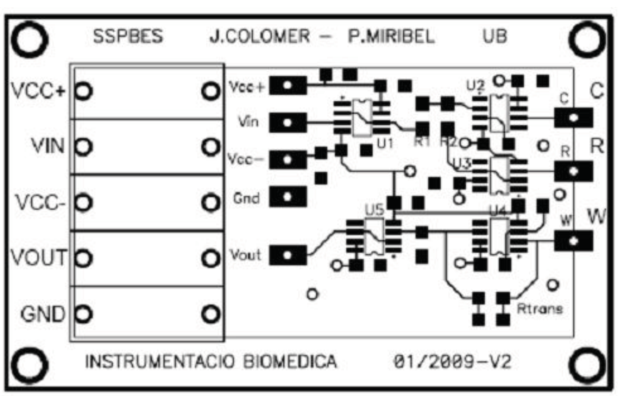


Fig.3: PCB representation of the biopotentiostat amplifier.

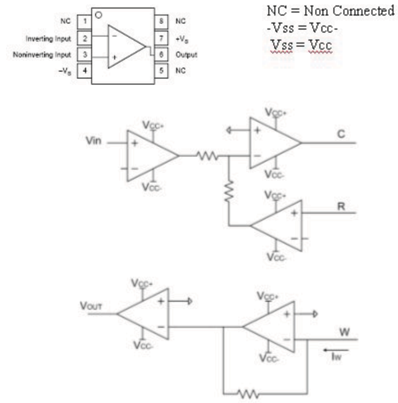


Fig.4: Caption of the exercise.

They must identify the different amplifiers that define the potentiostat amplifier, and find out the connections between the different elements, Fig.4. Following this technique all the students have a first contact with the PCB implementation before their experimental activities in the laboratory. The scheduled time for these activities, two hours, are more focused to run the different programmed measurements. This will make better time in the lab.

Activity A is focused to find out the mathematical expression that describes the relationship between the Working (W) and the Reference (R) electrodes with the input signal (Vin).

Also, for the students with an electric engineering profile, some more specific activities are programmed, and are used in order that they explain to their classmates the main reasons to select one amplifiers, and no others, for this design. The selected operational amplifier is the OPA 656 from Texas Instruments [27], which presents good parameters in terms of input impedance and offset voltage. They are requested to search the datasheet of this amplifier and compare it with some other amplifiers with worst and better characteristics like the LM741, LM725, LF411 and OPA124.

Fig.5: The instructor works with one group defining the CV measurement using Labview © interface of the programmed CV.

Activity B is focused to find out the sensor that has been used. The students only have the reference of the supplier (BVT Technologies) [28]. They must find its datasheet and identify the electrodes and their characteristics, and also will work the principles of the chemistry redox.The second part of the practical work is developed also in the classroom (second day), to work in a cooperative way. Previous activities concerning to each class are delivered, individually, to the teacher before the class, using the e-learning Moodle resources or e-mail. These are essential tasks for the individual evaluation of the students. Also, the students must indicate an approach to the time needed for them to complete the activities, which are estimated by us, around 2 hours and a half. Thanks to this work, out of the faculty, we are placing the students to prepare these activities before the work in group. If one of them fails, the whole qualification fails in the cooperative stage.

Following a three-step interview methodology [29-31], they must discuss the common activity and work on it together, the electronic background student (A student) should explain to the other students (B Student) its activity, in a basic academic language to be well understood for the rest of the group, and the B students introduce their research of the sensors to the A students. By the end of the class they should deliver a common report of the activity. Without this work finished and delivered to the professor before the laboratory activity, they can not go ahead with the activity, which is translated to a negative qualification.In the lab, part three, they proceed with the experimental measurements which are indicated in the student's laboratory manual. These activities are carried out during the second week. Work in the lab promotes interaction between students and the -laboratory equipments, with groups up to 20 members. In Fig.5 the instructor is working with one group, while they are taking a CV measures using LabView© interface.

During this session they are focused on the experimental part of the activity. The students work with a LabView©

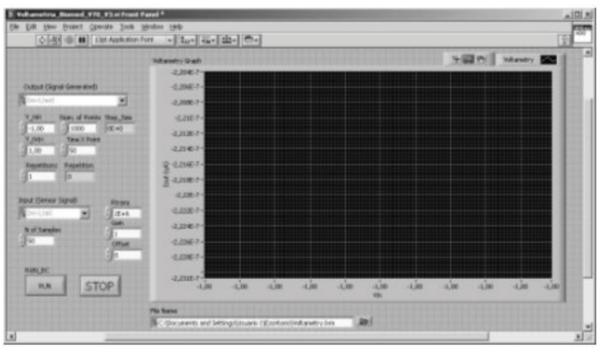


Fig.6: Interface of the programmed CV using Labview.

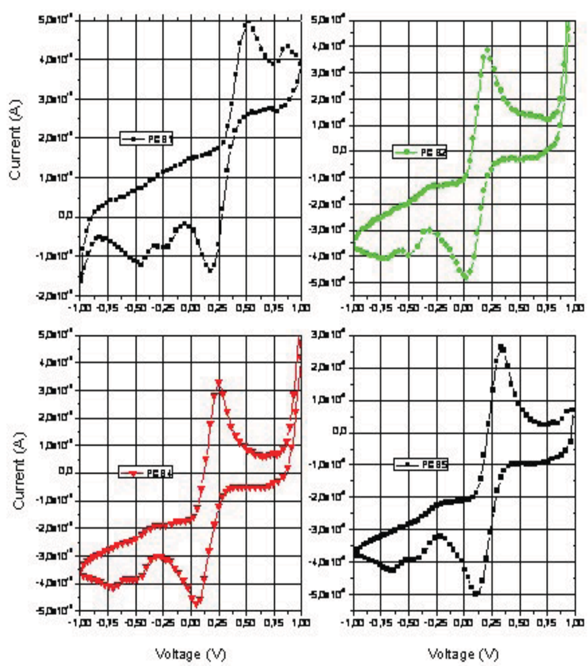


Fig.7: Different measurements programmed CV using Labview by the students.

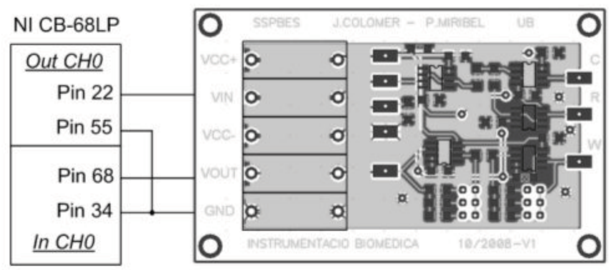


Fig.8: Interface connections between the PCB and the acquisition board.

Fig.9: Introduction review at the beginning of the lab session.

interface used to program and obtain the Cyclic voltammogram response (CV), defining the maximum (V_max), and minimum (V_min) voltage levels, time acquisition, in terms of the numbers of points (Num.of.Points), and the defined time of measurement for each point (TimeXpoint), Fig 6. The number of iterations for each CV can be defined (Repetitions) as well. They learn how the electronics are used to control the electrochemical reaction, basis of the electrochemistry. The CV, in terms of the current vs. the cycle voltage is depicted online in the panel, and the results can be browsed for their analysis, as shown in Fig.7. In the student's laboratory manual is described the right way that must be followed to bias the circuit, and the channels interface with the acquisition board, from National Instruments© (PCI-6014), as it is depicted in Fig.8. The instructor presents an introduction at the beginning of the session, Fig.9. Then, the students must prepare a report based on their measurements and some final questions. Reports are programmed to be presented to the professor before the next class, one week later. Also, the students must indicate the time needed by them to complete the report, which is also estimated around 2 hours and a half. At the end of the lab experience the monitor asks for a one minute paper [30]. That is a traditional technique followed in cooperative learning, and it is used in our case as a feedback measurement on where is the student's understanding of the material. Questions like: What was the most important or useful thing you learned today? Which three important questions do you still have? In the next class, the professor asks to the students following different strategies based on the feedback process: open random questions or short individual written examination. Also half of the class is used to solve the main student's doubts

IV. FEEDBACK FROM THE ACTIVITY

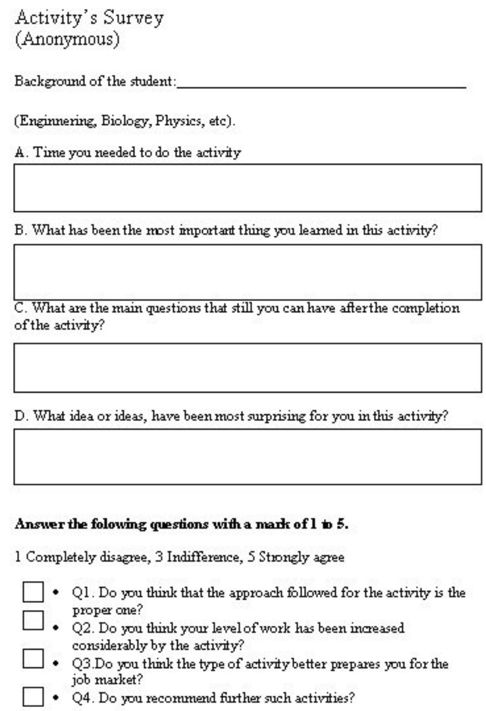
An interesting study has been also carried out between the students, which are not very keen on this type of activity. For this academic course we had 22 students, divided in four groups, as is indicated below in this section.

Figure 10 presents the survey used to know the opinion of the students about this activity. During this first experience we asked to them about their feeling about cooperative learning. From these surveys among them, we have analyzed their opinion and views on the full activity. These questionnaires are adapted from [33]. By using a defined scale, from 1(never) to 5(always), or 1 (strongly disagree) to 5 (completely agree), we have recollected the strengths and weaknesses of the activity.

In order to analyze these inputs, the curricular background of the students is required in the form.

The study was divided into four main groups depending on the background of students: Electrical & Electronics Engineering (7), Computer Engineering (4), Mechanical Engineering (2), Physics (4), Chemistry and Biology-Medicine (5). All students remark the interesting fact to know how they can relate the experience of a chemical reaction with the use of electronics' instrumentation for experiences that are the basis of spectroscopy.

Basically, the students with an electric and electronics engineering profile have an excellent comprehension of the involved electronics, and they focus their main interest in the experience, according to surveys, to the use of electronics in the functioning of the electrochemical experience. They highlight the fact that a potentiostat amplifier can be used in the measurement of chemical reaction and its biological applications. Their main concerns are related with the chemistry in the experience as it could be expected.


Activity's Survey
(Anonymous)

Background of the student:________________

(Engineering, Biology, Physics, etc).

A. Time you needed to do the activity

B. What has been the most important thing you learned in this activity?

C. What are the main questions that still you can have after the completion of the activity?

D. What idea or ideas, have been most surprising for you in this activity?

Answer the folowing questions with a mark of 1 to 5.

1 Completely disagree, 3 Indifference, 5 Strongly agree

- Q1. Do you think that the approach followed for the activity is the proper one?
- Q2. Do you think your level of work has been increased considerably by the activity?
- Q3.Do you think the type of activity better prepares you for the job market?
- Q4. Do you recommend further such activities?

Fig.10: Survey's form.

In the case of the rest of engineers, and for students with a degree in Physics, they have some difficulties with the electronics but they can cope with them with success. They have the same difficulties with chemistry linked with the laboratory experience.

As examples, these are some interesting answers of the students.

From question B of the survey: *What has been the most important thing you have learned in this activity*, they responded: "The use of chemical sensors, which I had never seen one, and I had no idea how they were and how they could be used, and thanks to the experience I have a first approximation.", by an Electrical and Electronic Engineer.
"I learned a visual and practical use of an electrochemical instrument", by a Mechanical Engineer.

For question C, *What are the main questions that still you can have after the completion of the activity?*, they say "My main doubt is related to the electronics", by a biologist. This answer is common in the group of chemistry, biology and Medicine students.
"My main problems were when I has to analyse the electronics", by a Physicits.
"The voltammogram response is a bit difficult for me to understand", by a Mechanical Engineer, very similar with comments by other students with an engineering brackground: "I do not understand very well the measured curve", by a Computer Engineer.

For question D, *What idea, or ideas, has/have been most suprising for you in this activity?,* the say: “The fact that an electric current is generated by a redox reaction and it is converted to a voltage that can be measured and processed.” by a Computer Engineer.

“The use of the electronics with the chemistry and sensors in the field of the introduced application and its use”, by a biologist student.

“It is for me the most surprising and new idea that I have learn from this experience that you would be able to measure biological concentrations using electronics”, by a Computer Engineer.

“The current detection by the electronics which is produced by the redox reaction”, by a Physicist.

“The application of electronics in biomedicine in general seems very important.” by an Electrical and Electronics Engingeer.

There are also some comments which are very grateful for the lab professors, like: “The attitude and involvement of teachers surprised me positively”, which is a great reward for teachers. In terms of the proposed experience, in general, and especially for the majority of students with a deficiency in training in electronics, the method has a high score, as it is shown for the different groups for question Q1, Fig.11.

What has been a great surprise is the average of indifference in terms of the work load for the students, question Q2. We expected a general sense in terms of an increase in the hours needed for the experience to be completed by the students.

Question Q3, designed to check the practical impact of it, in terms of a real job training approach, we have very different answers. In the particular case of the mechanical engineer’s profile, they mark this question with an average of “2”, which is a “disagree” opinion. Computer Engineering students and Biology-Chemistry and Medicine students have a good perception of this activity as a nice preparation for a real job.

Finally, question Q4 indicates a good perception of the students with this type of activity, which indicates a success in terms of the implementation of this kind of co-operative activity in this particular field.

The ECTS work of this activity represents 1/6 of the total activities of the students in this subject. Our first estimation was planned to be a total average of 10 hours. Thanks to the feedback collected from the students the real average time is around 12h.

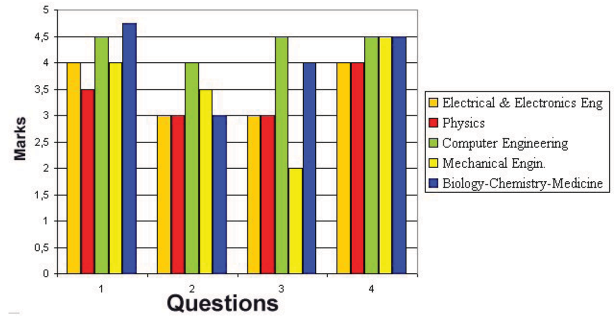


Fig.11: Mark’s report for survey questions Q1 to Q4.

V. CONCLUSIONS AND FUTURE WORK

This activity has been conceived to provide students with real hands-on experience. The focus of the activity was achieved for all students, regardless of their profile. They worked actively in the activity, having a good understanding of the experience, difficulties in more detailed aspects, but with success in the entire experience.
The students are introduced to one type of sensors and they work with the electronics involved in the design of a potentiostat amplifier, in its basic architecture. In this way they are introduced to commercial solutions but working in a design based on discrete components they are able to have an approach to its architecture. Also, in terms of cost it is more economic to have this discrete PCB for each working group that a commercial one. In this activity they work different clue aspects like the application of previous knowledge, the ability to work in multidisciplinary teams, communicate their results, etc ...

Teachers have noticed how all the students have understood the experience and they worked actively on it, particularly students with very weak foundation in electronics have been able to work with the track and understand the experience. No typical passive roles in the labs were present, which was one of the main concerns taking into account the diversity of the students.

Next year we would like to change the followed approach to increase the interaction between the students. The students with and engineering background will work just the sensors and chemical aspects of the activity, and the rest of student will work in the electronics. Then, they will work following a three-step interview methodology. In this case we expect a better interaction. The students will correct their classmates within the fields they have a better understanding and background.

It is also our purpose define new modules of experiences, like the Electrochemical Impedance Spectroscopy (EIS), and the use of lock-in amplifiers in the characterization of sensors and in the measurement of Electro Chemical Impedance Spectroscopy.

More in-depth analysis of the student's ECTS charge and comparative analysis of the qualification of the students following this kind of activity or traditional approaches will be presented in future works.

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An Undergraduate Microwave and RF Low-Profile Laboratory

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Abstract— **In this work, we present a complete set of undergraduate microwave and RF laboratory experiences, that have been designed to improve the students competences on the high-frequency design, analysis and characterization. The developed courses include one-port and two-port circuits' measurement and characterization with the current most used instruments: vector network analyzers, spectrum analyzers, noise figure analyzers and power-meters. The computer-aided design has not been overlooked: a *design-optimization-fabrication-measurement* process is proposed to improve the students' global vision of the subjects.**

Keywords-microwave circuits; antenna design; low-profile laboratory; computer-aided design and simulation; microstrip lines.

I. INTRODUCTION

Last decade has been characterized in education of electrical engineering for an overwhelming development of web-based software and/or CAD programs for low-cost simulations of technological phenomena [1,2]. Two positive consequences have been derived from this fact: firstly, budgets devoted to the acquisition of new laboratory equipment could be reduced -especially in recent engineering campuses-; and, secondly, subjects related to computer engineering have increased their presence in electric engineering syllabus. But also negative facts have appeared as drawbacks: on one hand, a high percentage of graduate students are not able to translate all the theoretical knowledge to real-world and, on the other hand, the academic formation in specialized areas of electrical engineering, such as high-frequency and microwaves, has decreased. This paper presents the development and adjustment of a low-profile laboratory for teaching high-frequency and microwave techniques in Electrical Engineering. As it was pointed-out in [3], special attention has to be paid to these laboratories, according to both the high cost of the electronic equipment and difficulties to achieve realistic designs and high-precision at these frequency ranges.

The high-frequency laboratory has to be useful for several courses of the Telecommunication and Electrical Engineering degree, all of them in the undergraduate last two semesters (the students are assumed to have a consistent knowledge of electromagnetic theory and analogical circuits and systems). The first of the courses to be taken is a basic introduction to microwave theory and techniques, including passive and active circuits design, as long as scattering (*S*) parameters analysis and measurement. Parallel to this subject, a second course is related to antenna theory, design and characterization, including radio-wave propagation theory. Finally, an advanced course on microwave circuit design, including circuit components of wireless transducers such as low-noise amplifiers (LNA), oscillators and mixers is also developed.

This paper is organized as follows. After this brief introduction, the two sets of experiences that have been developed for the laboratories are introduced in Sections II (microwave courses) and III (antennas and propagation course), respectively. Section IV discusses the competences that the students should develop after following the combined three proposed courses, and presents the main conclusions of this work.

II. MICROWAVE LABORATORY EXPERIENCES

The first three explained experiences (*II.A* to *II.C*) are oriented to the study of different characterization techniques and the involved instruments, while the last two ones (*II.D* and *II.E*) are useful to the microwave engineering process.

A. Two-port S Parameters Characterization with VNAs

One of the main parts of any elementary course on microwave circuits theory and design is the study of the *S* parameters [4], which overcome the problems that arise when applying the usual low-frequency characterization parameters (i. e., *Z*, *Y* or *H* parameters) to the microwave frequency range, where the voltage and current strongly depends on the reference position of the access transmission line. *S* parameters are based on power and phase measurements, which are measurable using standard coherent reception techniques. The students of Telecommunication and Electrical Engineering are used to these techniques and thus are able to fully understand the *S* parameters measurement.

In the laboratory, students learn how to use a *Vectorial Network Analyzer* (*VNA*), which is the most used instrument to characterize high-frequency circuits from a few *kHz* to over 100 GHz. To do so, it is essential to deal with two-port calibration techniques. Therefore, the students have to study and validate some of these techniques (such as *TOSM* – Thru/Open/Short/Match or *TRL* – *Thru/Reflect/Line*).

During the first of the courses developed on the microwave subject, the students characterize two-port passive networks,

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and study their properties taking into account the scattering parameters theory. In the second course, active devices (microwave amplifiers) are characterized using the *VNA*: the dependence of *S* parameters on the polarization is studied, and stability analyses are performed.

B. Microwave Characterization with Spectrum Analyzers

The use of *VNA* to characterize two-port or, in general, multiport circuits, is usually restricted to linear applications, as this equipment is based on the measurement of the circuit behavior at a single frequency, which is swept to perform broadband characterization.

However, this involves that non-linear effects, such as harmonic appearance or intermodulation products, are not observable without specific modules or instruments that, in most cases, are quite expensive [5].

One of the possible alternatives is the development of home-made control software to perform non-linear measurement with *VNAs*. However, a simpler approach is to make use of a high-frequency signal generator and a spectrum analyzer, each of them connected to one of the ports of the device under test (*DUT*). In this way, the power at the input and output planes is known. This technique, apart from allowing the students to learn how to use both instruments, gives them the idea of the basis of the *VNA*, as they measure a magnitude proportional to the transmission *S* coefficient. Moreover, the necessity of a calibration tool will arise in a natural way, since the students identify the frequency-varying probe loss (here, low quality probes and connectors are used to enhance this fact).

C. Noise Measurement and Characterization

Noise is a fundamental parameter on telecommunication systems, but undergraduate students do not usually have the opportunity to handle with real noise measurements. This is the reason why a *noise figure analyzer* has been included in the high-frequency laboratory.

During the second course on high-frequency circuits, the student has the opportunity to measure real circuits noise figure, including passive and active devices, and comparing the results with those expected from the theory.

D. CAD Design of High-Frequency Passive and Active Circuits

The main objective of this work is to show a set of experiences that allow the students to have a comprehensive formation on high-frequency design and characterization. In this context, we do think that computer-aided design is extremely useful for circuit design and optimization and therefore should be considered in any high frequency laboratory.

There are several commercial tools able to simulate RF and microwave circuits. Most of them allow the integration of 3D or 2.5D electromagnetic simulations within block system design, where simple models for each circuit part are used. Common examples of this kind of packages are *Agilent Advanced Design System* (*ADS*) [6], *AWR Corp. Microwave Office* [7] or *Ansoft Designer* [8]. However, their correct use calls for an intense training that is not achievable in a one semester course. Moreover, only some of these codes are available in student versions, and these versions are usually truncated so that most of their functionality is missing.

As the solution of the Maxwell equations via numerical methods is necessary in the antenna design and optimization process, the CAD-aided design in the microwave laboratory has been centered on the model-based simulation of planar transmission lines. One good code based on transmission line models is *PUFF* [9]. This code was developed in the last 80's and it has been used for more than one decade in the academic environment. Its main advantages over the professional tools are:

1. It is more intuitive, as it allows the students to *see* the circuit they are simulating, in contrast to other model-based simulators.
2. Implemented models are simple but enough accurate for an introductory course.
3. It is a low-cost tool, in contrast with most of the commercial codes.

Following its example, we have developed *MWSim* [10], a model-based simulator. Its main differences with the *PUFF* code are: *i)* an updated to current standards graphic user interface, *ii)* a larger variety of microstrip models, performing more accurate results and allowing the comparison with other commercial tools, *iii)* an input/output format fully compatible with standard *Touchstone* (which allows the use of embedding and de-embedding techniques with VNA measurements and with electromagnetic simulators) and *iv)* it includes the possibility of exporting files into *Gerber* format [11]. The last option is of special importance as the students are able to export the geometry file of the designs and fabricate them using automatic milling machines, which is the objective of the experience IIE.

The students of the advanced course are encouraged to work with this tool and also with evaluation/student versions of commercial tools in order to compare the obtained results. With these comparisons, a twofold objective is tackled. First, the students get a better understanding and critical assessment on the models validity. And second, the use of the evaluation versions of commercial tools might be useful in their future professional life.

E. Microwave Passive Device Fabrication and Characterization

The engineering process in the designed laboratory does not stop on the design, simulation and optimization steps. In order to give the students the opportunity to build their prototypes, and characterize them by using the techniques they have already studied in experiences *II.A* to *II.C*, they are allowed to export the geometry of their designs into standard Gerber files, which can be fabricated using a milling machine. Thus, the laboratory has been equipped with the *LPKF* Protomat S62.

As the objective of the exercise is not to obtain professional prototypes, but to provide the students a general overview of the design to fabrication and characterization process, these designs are fabricated on Double-Sided Standard FR4 PCBs, which are quite cheap and allow well-working designs up to a few GHz [12]. Moreover, in this range of frequencies high-frequency milling tools are not necessary, and therefore the milling process becomes cheaper.

Fig. 2 shows a microstrip circuit (branch-line coupler) that was simulated with *MWSim*, exported to Gerber and fabricated using the milling machine. Although the objective of this paper is not to introduce the results of the comparison between measurements and simulated data, it is worth to say that a very good agreement is usually found between them [10]. From a didactic point of view, this helps the students to understand how the abstract concepts they theoretically study can be translated into practical circuits, which they can fabricate and measure.

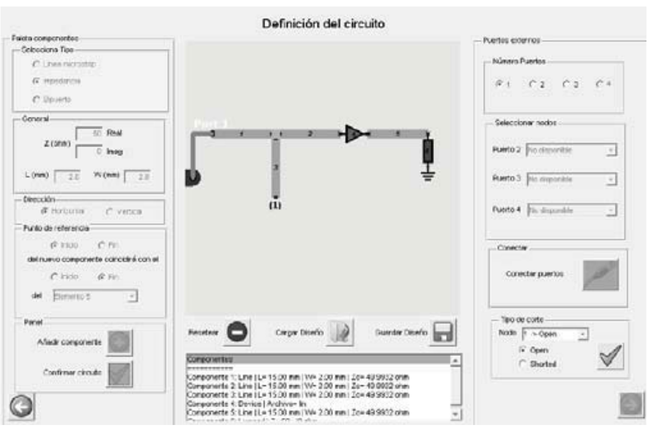

Figure 1. MWSim simulator: front-end user interface.

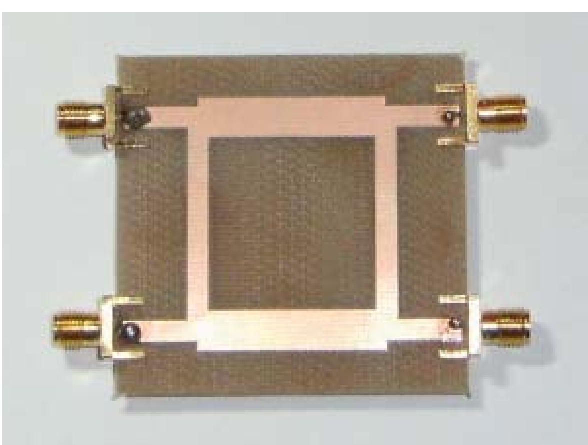

Figure 2. Microstrip circuit (branch-line copuler) designed with *MWSim* and fabricated with a milling machine using a double-side PCB and low-frequency mill tools.

III. ANTENNAS AND PROPAGATION EXPERIENCES

Experiences in this field are strongly related with those from Section II. Most of the experiments are performed in parallel with those described in Sections *II.A*, *II.B* and *II.D*, although more emphasis is made in the measurement and validation of one-port devices. Further, radiowave propagation and derivation of antenna parameters, and in some way the CAD design of antenna, constitute the new set of practical knowledge acquired by the students in this subject.

A. High-frequency Laboratory Equipment for One-port Measurements

Experiments related to this objective are focused in the use of the *Vectorial Network Analyzer* in one-port mode as well as the use of a *Spectrum Analyzer* with internal tracking generator as Scalar Network Analyzer. Additional efforts are made in this stage to perform measurements of the time-domain impulsive response of the antennas, as an alternative way to characterize the broadband and ultrawideband devices, matter of hot interest in the industry industry in applications related to both goniometry and impulsive radar fields [13]. Figure III shows a picture of the control panel of home-made software based on *LABVIEW* [14] and designed for time-domain characterization purposes.

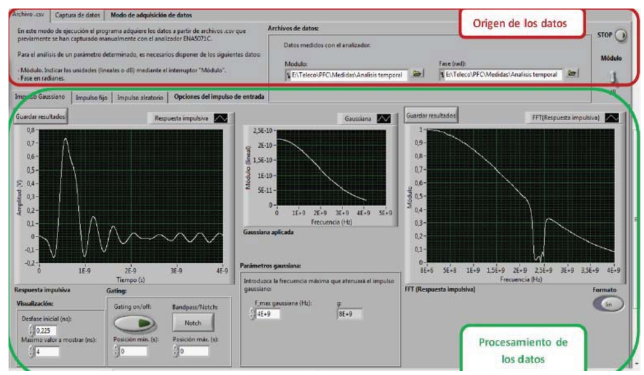

Figure 3. Software tool for the measurement of time-domain impulsive responses.

B. Practical Measurements of Antenna Parameters and Propagation Effects

Simple transmit/receive configurations can illustrate basic effects -mainly associated to antenna properties and radiowave propagation- which are involved in real-world wireless communications. Most of the available educational kits at affordable prices are devoted to this purpose, being the dimension of the laboratory a critical parameter in this choice. In our case a commercial X-Band antenna kit was chosen, being able to illustrate the effects in a real anechoic chamber related with the positioning and calibration of the system.

C. Mesurements of In-site Radiowave Spectrum

Acting as a complementary experience to *III.B*, the students should be set to perform in-site electromagnetic radiation measurements. Then, the first step is to guide them into the identification of radiowave signals for a specific place, which is done not only by looking at specific ranges of electromagnetic spectra, e. g. WiFI 802.11 emissions, but also by consulting the public information provided by Spanish Government related to the allowance of the emissions for the different TV and radiochannels [15]. Once done, they further compare measurements by using calibrated professional equipment for radiowave measurements and radioelectrical planning, and by using a set-up of laboratory equipment for non-calibrated measurements of radio and microwave spectra – basically a log-periodic array of antennas connected to a spectrum analyzer. Excellent agreement is achieved for identification purposes, but some considerations about the level of the received signals are arisen from the use of non-calibrated equipment.

D. CAD of High Frequency Wireless Communications

This experience presents different alternatives to the computer-aided design of antennas. Rather than focus in aspects related to particular software, these experiences are oriented to show the theoretical basis of commercial packages [16], and the limitations presented for carrying out the designs to prototypes. Hence, special attention is paid to the physical geometry of the antenna as a major factor for the choice between the high-number of CAD for antenna design, and some time is devoted to the limited number of wireless and radiopropagation tools available in the market.

E. Fabrication and Measurement of Antennas

As a final step, the manufacturing of planar and microstrip antennas, as well as the measurement of their radiation parameters, can be made by employing high-frequency milling machine and SMD tools, starting from CAD student's simulations. This stage is understood as a final evaluation of the maturity of the student, and lead to results as shown in Figure 4.

Figure 4. Example of a 2.4 GHz patch antenna.

IV. Discussion and Conclusions

The experiences that have been presented in Sections II and III have been developed during various semesters, and a continuous effort is being made to provide the students the best possible education in the subjects related to microwave and radiofrequency guided and wireless communications. Working together, efforts have been summed to have a laboratory as functional as possible.

The laboratory contains a couple of two-port VNAs, with their corresponding calibration kits and RF probes, six couples of microwave generators and spectrum analyzers, a noise figure analyzer, a milling machine, and a PC for every student.

With this equipment, during two semesters, the students are able to work in the laboratory under an expert supervision. These are the main abilities they acquire during this period:

1. Operation of specific high-frequency equipment. Specifically, they learn how to use the VNAs to characterize both multiport circuits and monoport ones (antenna), including the appropriate calibration techniques for each of them.
2. Simulation of microwave guided and wireless circuits, including both commercial and home-made simulators, and making use of both electromagnetic simulation schemes and model-based tools.
3. In-depth knowledge of the full “design to characterization” RF engineering process, including the simulation, optimization and fabrication steps.

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Session 02D Area 2: Laboratory Experiences: on-site and remote environments - Remote Labs

Easily Integrable platform for the deployment of a remote laboratory for microcontrollers

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A Remote Laboratory to Promote the Interaction between University and Secondary Education

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SecondLab: A Remote Laboratory under Second Life

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Hardware Implementation of Remote Laboratory for Digital Electronics

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Easily Integrable platform for the deployment of a Remote Laboratory for microcontrollers

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***Abstract*—Remote laboratories are the natural solution in order to perform real experimentation under e-learning tools. Nevertheless these tools are the result of the research developed by the universities to cover their own needs without having in consideration the deployment of this technology by other institutions. This paper presents a hw prototype for a Remote Lab for microcontrollers that tries to solve these problems contributing new possibilities from the commercial and professional point of view.**

Remote laboratory; e-learning platform; microcontrollers

I. Introduction

The advantages offered by e-learning platforms have caused important changes in education. However certain technical studies require the use of laboratories where develop real experiments with a greater didactic capacity than simulators [1].

Nowadays, the use of Remote Laboratories in universities is extending widely. A Remote Lab is a combination of hardware and software which allows a student to complete lab assignments remotely, e.g. from his home, just as if she was present in a laboratory. The student remotely controls the devices in the laboratory through a web interface, and monitors the outputs resulted from her interaction through a WebCam, a data file or using other electronic measuring instruments like oscilloscope or multimeter.

II. Actual Scenario

Since the end of the 20th century, Remote Labs fill a very active research field in e-learning, and during the last five years the number of universities working on new Remote Labs has been multiplied. However, most of these new solutions do not match a professional level.

The fact that very few projects have been exported to other universities is just a proof of this statement. The most remarkable examples of this would be the VISIR Project [2] (BTH-Sweden) and the iLabs (MIT – USA) [3]. Another proof is that there is no market of commercial Remote Laboratories, neither a company supporting them, except National Instruments (NI).

The technical reasons behind this lack of professional or commercial projects in remote experimentation are the deficiencies of the software and hardware underneath.

From the point of view of the software, many Remote Labs have been developed without matching even minimum requirements. For instance, in a research asking 10 researchers in remote experimentation (MIT, BTH, EPFL, etc.) what features were more important for the development of a Remote Lab, the preferred ones were those related with software aspects (security, cross-platform, supported web browsers, etc.) instead of those related with hardware aspects (frequency, accuracy, etc.).

This shortage can only be addressed by designing the Remote Laboratory focusing appropriately on the software design and technologies used –as in the WebLab-Deusto Project using Web 2.0 technologies [4] (U.Deusto, Spain)–, or designing the Remote Laboratory on top of a LMS (Moodle, .LRN, Sakai, etc.) that will provide many transversal aspects of any Remote Laboratory.

On the other side, from the hardware viewpoint, the biggest problem is that the experiment is not autonomous, so part of its basic functionality is tightly coupled to the software side. It is usually difficult to isolate the hardware from the software providing the experiment, so it is not possible to unstuck the hardware side of the project and deploy it on other platform (such as an LMS) easily.

The users of a Remote Lab are the teachers and the students, and also the university. So a Remote Lab must be focused on teachers and students. Usually the teachers' requirements are forgotten by the researchers (because they usually will be the teachers). The teachers need a tool easy to install, to use, to manage, etc., more or less as Moodle is for them. The question is, are the Remote Labs easy to deploy? The answer is no, attending to the lack of deployed or commercialized Remote Laboratories.

Imagine that a high school want to install a Remote Laboratory, is it possible? Not today

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III. Previous Approximation

Due to the scenario described in the previous paragraph, during 2008 the Faculty of Engineering of the University of Deusto developed a Remote Laboratory in order to achieve two targets: get a low cost and easy to install platform [5].

After analyzing the architectures adopted in most known Remote Laboratories we come to the conclusion that all of them were based on a robust server (or more of one in some cases) entrusted of carrying out the tasks of interaction with the experiment and with the user.

The software installed in the server, designed generally in proportion to the particular needs of the developer university, impedes the deployment of the Remote Laboratory in other infrastructures and increases the cost of the final system. Therefore it is logical to think that eliminating the server of the architecture obtains a solution easier to install and certainly more economic.

Advances experienced by 8 bits microcontrollers during the last years allows to have low cost microservers where implement the tasks carried out previously by the computers. The selected microcontroller was the PIC18F97J60 launched by Microchip®, which includes an Ethernet controller inside as well as an incredible performance and diversity of resources to be a microcontroller of 8 bits.

Specifically, the WebLab-DEUSTO-PIC V0.1 is based on a system that implements two PIC18F97J60 microcontrollers that play different roles: Experiment and Server. The first one will run the program uploaded by the student, whereas the second one, the microserver, will allow the client to interact with the experiment: Upload the file to test, passwords control, inputs/outputs, etc. The microcontroller entrusted to execute the program created by the student is programmed with a bootloader, that is able to allocate in the program memory and execute a hex file received by tftp protocol. (“Fig. 1”)

Figure 1. WebLab-DEUSTO-PIC v0.1 prototype

Student connects to the microserver using any web browser, log in with a password and once he is authorized he just can select the file that contains the program to test and upload it to the Remote Laboratory through a simple web page.

The file then is sent through simple tftp protocol to the microcontroller in charge of the experiment, which interrupts the execution of the previously loaded program when the reception of an UDP packet is detected, and the resident bootloader loads new hexadecimal file in the program memory of the microcontroller. Then new program is executed by the microcontroller until it is replaced with other one by the same or other student. The student that uploads a file is automatically redirected to other web page (“Fig. 2”), where he can experiment changing values of the inputs and monitoring the resultant outputs.

The employment of microservers contributes to the system two clear advantages:

- The cost of the complete system is lower than 200€.
- Being both cards, experiment and microserver compatible with the DHCP protocol, the installation of the system in any infrastructure is so simple as to power both cards and to connect them to the Ethernet network being accessible from moment the cards acquire IP addresses. This is what we name a Plug&Play installation.

In the other hand, the limitations imposed by the microservers determine certain functional aspects of the Remote Laboratory:

- The limited performance of the selected microcontroller generates problems in moments of concurrent access.
- Tasks of management (administration of the users' queue, authentication, etc.) meet limited by the protocols included in the TCP/IP stack implemented by the microcontroller manufacturer.
- Being impossible to use a Webcam the monitoring of the outputs takes place across a web page losing realism in the development of the experiment.
- The resultant Remote Laboratory is not extensible to other laboratories further tan microcontrollers (CPLD, FPGA, etc.).
- It turns out to be very complicated to integrate the laboratory inside any e-learning platform.

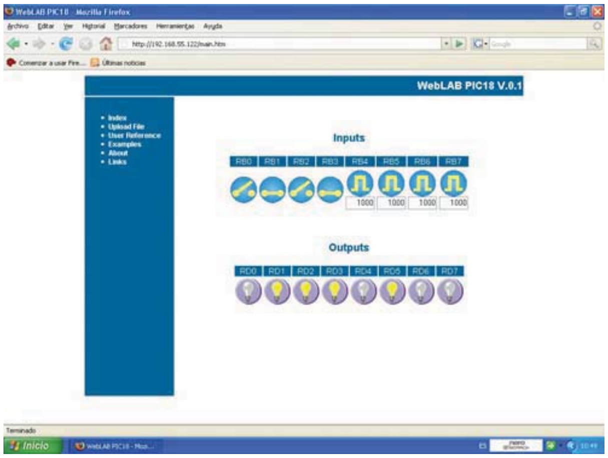

Figure 2. Web page for interacting with the experiment


Figure 3. WebLAB-DEUSTO-PIC V2.0

IV. Proposed Solution

In the Faculty of Engineering of the University of Deusto play the role of users and developers of Remote Laboratories. This double point of view has allowed us to assure us on the one hand of the enormous didactic capacity of these tools as of the difficulty of its design and development as well as of the integration in an existing infrastructure like it can be the network and educative process of one university or school. This difficulty practically limits the use of Remote Laboratories to institutions with capacity for the research: universities. For this motive we have overturned our efforts in the design of a platform looking for a massive implantation in diverse educational centers on the basis of three fundaments:

- The Remote Laboratory must be a stable system. In order that the teacher considers the Remote Laboratory as any other didactic tool it must cause the minimal problems. In many occasions, the Remote Laboratories never pass from the state of prototype and the hardware is capable to external aspects like that a wire is disconnected because it hasn't a definitive connector or that the Webcam goes out of focus on not having been properly anchored. For these reasons the Remote Laboratory must have a professional appearance and the whole interaction between the teacher and the system must be to user´s level making independent the tasks of developer and teacher completely. ("Fig. 3")
- The Remote Laboratory must be adaptable. The deployment of the system does not have to provoke a substantial change in the system of learning. It must adapt to the E-Learning platforms used by every educational center joining as one more resource inside it. Compatibility with Moodle, .LRN, Sakai or other learning platforms must be implemented.
- The Remote Laboratory must be extensible. Although it´s been designed for teaching PIC microcontrollers, the architecture must support any other laboratory as other microcontrollers (Atmel, Freescale, etc.), DSP, CPLD, FPGA or any other programmable device.

V. Architecture Of WebLab-DEUSTO-PIC v2.0

In order to achieve that the laboratory is extensible it has divided in the following parts: ("Fig. 4")

A. *Experiment board*

This board contains a microcontroller PIC18F97J60 on which the student will program the developed project. In this system the programming is carried out across the Ethernet network through a bootloader that receives the content to program in the memory of the microcontroller by tftp protocol. Being independent of the inputs and outputs it can be replaced for other including other device as a CPLD, a FPGA or p. e. an Atmel µcontroller. Although it is convenient, in order to facilitate the assembling, it is not necessary to program the device through a TCP/IP protocol being possible to access to the USB ports of the server.

B. *Inputs board*

This board allows the student to manipulate the signals received by the experiment board. This board is also based in a PIC18F97J60 that receives from the interactive web page, through POST commands, the orders to set/reset digital inputs, change the value of analog inputs, receive serial data through UART port or any other kind of signal according to the nature of the experiment.

C. *Outputs board*

This board allows the student to watch, through the Internet camera, the outputs of the experiment. It can be designed customized for the experiment including most appropriate output peripherals. In WebLab-DEUSTO-PIC V2.0 it includes next elements:

- Two alphanumeric 2x16 LCD, one for experiment with the proper LCD and other one to visualize the information sent across the UART port.
- 8 LEDs directly connected to port B to manipulate digital outputs.

- 8 LEDs connected through an I^2C port expander (MCP23008) to experiment with Inter-Integrate Circuit Bus.
- 8 LEDs connected through a SPI port expander (MCP23S08) to experiment with Serial Peripheral Interface Bus.
- Futaba continuous rotation servo connected through a driver to experiment with PWM.

D. DCS-5220 wireless motorized pan/tilt network camera

Internet camera is placed over the outputs board allowing the student to watch the behavior of the experiment. Due to the size of the Outputs Card, it is convenient that the student can manage the camera focusing the part of the board involved in his own experiment. Interactive web page includes a control to move the camera.

E. Fit-pc2 server

The last advances in low format computers allow to arrange a powerful computer with small dimensions and low cost. New Intel Athom based computers make the employment of microservers slightly efficient being able to acquire robust servers, compatible with operating systems like Windows 7® or Linux, that facilitate the development and the integration of the Remote Laboratory with similar dimensions and price. In WebLab-DEUSTO-PIC V2.0 a fit-pc2 (“Fig. 4”) by Compulab has been incorporated to arrange all the management tasks needed by the experiment. Characteristics of this device are mentioned in “*Table I”*. Functions to be done by this computer depend on the operational mode selected as is explained later.

TABLE I. FIT-PC2 SPECIFICATIONS

Features	
CPU	Intel Atom Z530 1.6GHz
Chipset	Intel US15W SCH
Memory	1GB DDR2-533 on-board
Storage	160Gb 2.5″ SATA HDD
Display	Intel GMA500 graphics acceleration DVI Digital output up to 1920 x 1200
Networking	1000 BaseT Ethernet 802.11g WLAN
USB	6 USB 2.0 High Speed ports
IR	Programmable consumer IR receiver
Mechanical and Environmental	
Dimensions	101 x 115 x 27 mm
Case	100% aluminum die cast body
Weight	370 grams / 13 ounces – including hard disk
Power Consumption	6W at low CPU load <7W at 1080p H.264 playback 8W at full CPU load <1W at standby

Figure 4. Low format computer “fit-pc2”

F. 5 Port Fast Ethernet Switch

To simplify the connection of all the elements with Ethernet connectivity to the network of the infrastructure the system has internally a Switch that interconnects them offering an only one RJ45 connector for its installation

G. Power Supply

25W Switching Power Supply, 5V/2,5A and 12V/1A Dual Output Voltage. Other output voltages and output models needed from other experiments are available with the same dimensions.

To decouple the hardware from the software allows to perform several experiments of different nature changing only two boards involved in the experiment: *Experiment board*, including one containing selected device and the logic to program it and *Outputs board* selecting the proper output peripherals for the experiment. (“Fig. 5”)

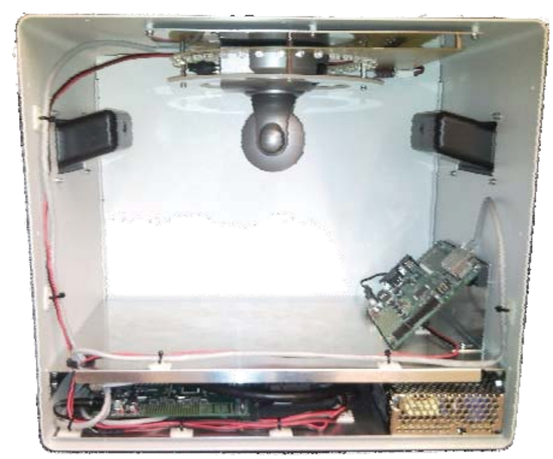

Figure 5. Transversal section of WebLAB-DEUSTO PIC V2.0

VI. FUNCTIONAL CHARACTERISTICS OF WEBLAB-DEUSTO-PIC V2.0

To facilitate the deployment of this Remote Laboratory adjusting to the needs of any educational center the WebLab-DEUSTO-PIC V2.0 can work according to 4 different operational modes:

- ***Plug&Play Operational mode:*** This is the stand alone mode. None other element is required to perform the experiment. The inside computer realizes all administrative tasks: user authentication, user´s queue management and log files generation so as the tasks related with the experiment: program the experiment board with the user hexadecimal file, serve the interactive web page and order to the inputs board all changes demanded by the user. "Fig. 6" shows a snapshot of the interactive web page working in this operational mode. Taking advantage of the high performance provided for fit-pc2 included WebLab-DEUSTO-PIC V2.0 provides a completely autonomous Remote Laboratory with a high degree of integration on the part of the student.

- ***Integrated on WebLab-DEUSTO platform:*** The award-winning WebLab-Deusto project provides a web-based, experiment-agnostic, scalable software infrastructure which permits the University of Deusto to offer several laboratories to its students through the internet [6]. This platform is the result of years of research and provides perfect functionality for the development of remote experiments. The architecture is based in a central server in charge of all the management tasks and a microserver per experiment giving support to the communication with the specific hardware. Microserver task are implemented on the fit-pc2 simplifying integration with the platform. Concurrent similar experiments are allowed reducing significantly waiting times of the students, one of the constraints in the use of Remote Laboratory in the same way that happens in on site ones. (“Fig. 7”)

Figure 6. WebLab-DEUSTO-PIC v2.0 interactive web page.

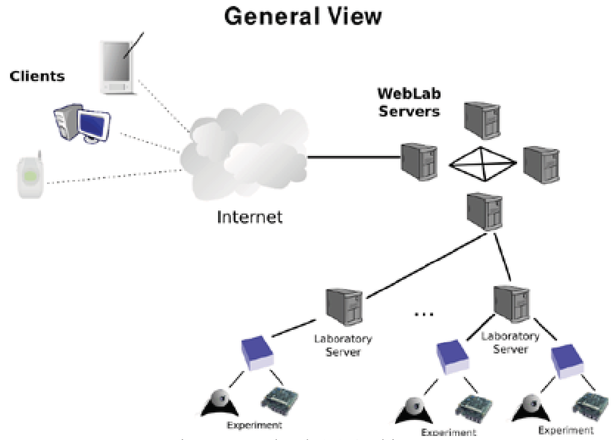

Figure 7. WebLab 3.0 Architecture

- ***Integrated in a learning platform:*** Employment of learning management systems (LMS) gains acceptance amongst educational institutions and their students. Integrate a Remote Laboratory on the institutional platform as one more resource offered improves the satisfaction obtained by the student simplifying the task of the teacher. WebLab-DEUSTO-PIC v2.0 is in process of being integrated on Moodle. A proper integration must allow include an experiment as if it were more available activity such as a questionnaire. Tasks of user authentication, storage of files uploaded by students and user´s queue management must tu be performed by Moodle while the tasks of the experiment shall run on the fit-pc2. Due to the large number and diversity of learning platforms is difficult implement a solution for various systems, but the use of standards and the experience acquired with Moodle must simplify the integration on other LMS as .LRN or Sakai [7].

- ***Ready for xLAB integration:*** The University of Deusto is actively involved in developing the new platform for Remote Laboratories “xLab” in collaboration with the Massachusetts Institute of Technology (MIT) pretending that the WebLab-DEUSTO-PIC v2.0 is one of the first laboratories offered under the same [8].

Regardless of the operational mode chosen, the hardware installation process is simple. All elements included: the outputs board, the inputs board, the experiment board, and internet camera support an announce protocol that provides access to their IP addresses in a simple manner. When the WebLab-DEUSTO-PIC v2.0 is plugged on the institutional network, the inside computer detects each device connected to the lab network and saves in one xml file the IP addresses assigned to each device. Simply configure the inside computer to access the full experiment.

In addition in any operational mode the process of interaction is the same:

- The authorized student generates a binary file using preferred development environment (for example MPLAB IDE). The process of editing and assembling the program is intentionally removed from the laboratory allowing the student to use desired development tool and programming language in each moment
- Student connects to the Remote Lab waiting for his or her turn in case other students are using the lab. System manages user´s queue trying to minimize waiting periods.
- When the student takes control of the lab via a web page selects the file to program the PIC microcontroller included in the experiment board. The file is sent through tftp protocol using the bootloader included preprogrammed in the microcontroller. The functionality of the bootloader is easy, after a reset the program waits 5 seconds to receive a binary file through tftp. If within that period, file is not received bootloader runs the last program stored, however if it receives a file compatible with the microcontroller, content is stored in program memory and bootloader launches the execution of the new program. The system should cause a reset in the experiment board before sending the file tftp. The reset is generated by the inputs board when receives a RESET POST command from the system.
- Automatically, after PIC is programmed system opens the interactive web page that allows the user to check the operation of the program. For 60 seconds (obviously timeout is configurable according with the experiment), the student can modify the value of the inputs from this web as seen on "Fig. 6" and monitor the result through the internet camera focusing the outputs board. Currently the interactive page allows control of 5 digital inputs whose value can be set or reset, three digital inputs that are activated during a period specified in milliseconds, two analog inputs whose value is selected through a list and allows the sending of a string through the asynchronous serial port (UART) by means of a text field.
- After this time, student is automatically asked to be relocated on the bottom of the user´s queue.

VII. Deployment of the WebLab-DEUSTO-PIC v2.0 on a Subject

Since the development of Remote Laboratory WebLab-DEUSTO-PIC v2.0 has been delayed until early November 2009 his employment in a real subject was not conducted until the second semester of course 2009-2010. The first course that will use this resource is "Digital Electronic Systems" belonging to the second year of the degree in Telecommunication Engineering in the Faculty of Engineering, University of Deusto.

This experience will determine the satisfaction of the students and teacher as a result of using the system. The teacher of the selected course has not participated in developing the system beyond the requirements analysis.

Based on the results obtained in this pilot, from the next academic year WebLab- DEUSTO -PIC v2.0 will be deployed on other subjects of the same nature.

VIII. Conclusions and future

Main contributions of the presented WebLab-DEUSTO-PIC are focused in improving three fundamental characteristics in a remote laboratory: stability, adaptability and extensibility. The employment of the system in a real subject during the second semester of the course 2009-2010 will serve to measure the improvement with regard to other remote laboratories used previously.

In the near future work will be focussed on next objectives:

- Integrate the system in learning platforms type Moodle.
- Implement more units to study the improvement in student satisfaction having several similar laboratories concurrently with the consequent decrease in waiting times.
- Integrate new devices (DSP, CPLD, etc.) over the designed platform.

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A Remote Laboratory to Promote the Interaction between University and Secondary Education.

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Abstract— **iLabRS is a remote laboratory developed in Telecom BCN, the Telecom and Electronics Engineering School of the UPC with the key participation of a Secondary Education Technology teacher. Students and teachers can access to real experiments in the electronics and physics areas using a web browser. The remote experiments have been designed to partially cover the technology curriculum in the last two high school years with a triple goal: (1) to enrich the set of laboratory experiences available in High Schools, (2) to provide a clear example of the possibilities of internet-based technologies and (3) to promote the interaction between University and Secondary Education. Currently, there are 13 different experiments available. A pilot evaluation experience was carried out, in collaboration with 7 High Schools and around 100 students participating. In the experience assessment, the students gave a mark of 3.8/5 and the teachers of 4.4/5.**

Keywords- Remote laboratory; Secondary Education; Student engagement.

I. Introduction

Engineering studies, and more specifically, Information and Communication Technologies (ICT) related higher education studies have suffered a decrease in the incoming students from Secondary Education in the last years. Several initiatives are being carried out, mainly in the western countries, to promote the technological and engineering vocations. In ETSETB-Telecom BCN, the Telecom and Electronics Engineering School of Universitat Politècnica de Catalunya (UPC), placed in Barcelona, an existing modular remote laboratory platform [1] has been adapted to provide remote access to real experiments to Secondary Education students, as a way to increase their technological knowledge and skills but also to promote the interaction between the Secondary Education students and teachers and the University.

Remote laboratories are usually developed to enhance the conventional educational experiences and to optimize the use of resources [2], [3]. Leaving aside virtual laboratories based only on simulation, there is a considerable amount of remote laboratories that provide real-time access to real instruments. There are educational research lines devoted to the study of this topic [4]. Most of the remote labs for engineering education are in control [5],[6],[7] and electronics or circuit theory [8],[9],[10] areas. A good review of developments in the systems engineering area can be found in [11]. The aim of remote laboratories could be to provide complementary learning tools but also to provide facilities to access to big or singular equipments [12] or even to fully implement the laboratory activities [13]. Two literature reviews can be found in [14] and [15].

Almost all remote laboratories which have been reported have been designed and implemented to be used in the University frame. Meanwhile, Primary and secondary school students and teachers have access to a vast amount of internet-based resources. In our knowledge, almost all of them are virtual demonstrators, which are usually based on Java applets or flash animations, and very few of them are based on remote laboratories with real experiments [16], [17].

The remote laboratory described in this communication was initially designed to fulfill the needs of an advanced course in Electronics Engineering. However, it has been adapted to provide formative activities to Secondary School students. It has been possible thanks to the collaboration between the Telecom BCN staff, which includes our faculties, granted students and the IT staff, and Francesc Garófano, a Secondary Education teacher that spent a full sabbatical year in the development of both technical and didactical aspects of the remote laboratory.

In this communication we will mainly describe the non reported pilot experience that was carried out in 2008 with seven High Schools, involving around 100 students.

Nowadays, work is focused on developing new experiments, building more replicas of existing experiments and designing a complete software application to manage access to resources in terms of organization, security and accessibility.

II. Remote laboratory

iLabRS has been built over our custom modular platform [1] to develop remote laboratories in the instrumentation and sensors field. It is based on a main board that one of its functionalities is to provide a custom acquisition system around an Ethernet-capable microcontroller. The specific experiment circuit boards (10x10 cm) are connected to the corresponding main board in a sandwich structure (Figure 1).

Figure 1. A main board with the experiment board 2 connected on its top. It implements a configurable linear power supply.

The main board has a single 5V input power supply and provides +/- 5V to the daughter board. The connection between both cards also include 4 A/D and D/A channels, 8 I/O bits and a selectable serial bus (SPI/I2C). iLabRS structure consists of several main boards, each of them with its own IP address, connected into a LAN through a switch with a dedicated server. This server is in charge of running the NI - LabView programs which implement the user interface and control. Teachers or students can perform experiments using a web browser to access to the iLabRS web site (http://ilabrs.etsetb.upc.edu), which contains didactic materials for each experiment and also the url to the LabView remote panel (Figure 2) which gives the control of the experiment.

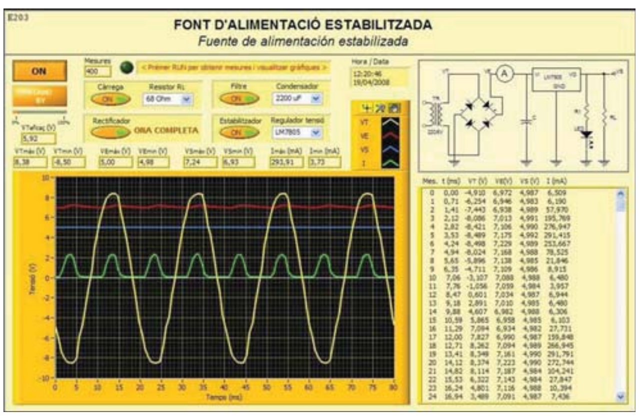

Figure 2. Remote panel corresponding to an experiment which deals with a regulated power supply. The students can see the schematic with the voltage and current symbols and read their instantaneous and time series. Several parameters (filter capacitor, load resistor) can be changed and the circuit configuration (half/full wave rectifier, insert regulator) can be selected.

At this time, up to 13 remote experiments corresponding to the Technology curricula of the two last High School years can be performed. Figure 3 shows the 10 boards that implement these experiments. There are three boards that can implement several experiments each one, and which are replicated three times. Experiments have been replicated because usually in High Schools all the students are moved to the computer room to perform a guided session by the teacher around one or two remote experiments while in the university courses are mainly used by the individual students from their homes. An additional board (left of the figure 3) implements a singular experiment (strain - stress measurement). The currently available experiments list is the following:

- Board 1: I/V characteristic curve of a resistor, silicon diode, germanium diode, LED and zener diode, all of them both in direct and inverse polarization. The experiment consists of performing a voltage sweep from -5V to 5V through a resistor. Also includes a capacitor's charge and discharge process and time constant RC concept.
- Board 2: Basic linear power supply circuit. Components are a full/half wave diode rectifier, capacitor filter and a linear voltage regulator. Activities involve voltage and current measurements for different load resistor and filter capacitor values to determine ripple, linear regulator drop-out,..
- Board 3: Implements a basic transistor circuit characterization. It is possible to measure input and output characteristics, load line, operating point and gain. Input and output circuit resistors and voltages can be changed at any time and the device under test also can be switched between a signal and a power transistor.
- Board 4: Strain-stress characteristic of a polymer sample. The experiment controls a linear stepper motor and measures the output signal of a displacement and a force sensor. The motor can be operated manually or set in an automatic mode to obtain the up and down strain-stress characteristics of the sample. Proposed students activities consist of determining force constant using Hooke's law and determining hystheresis among others.

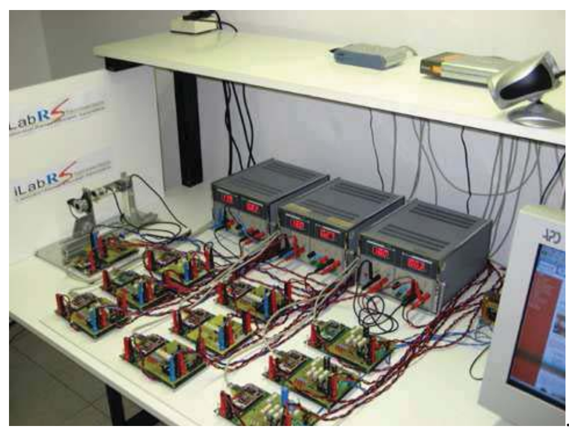

Figure 3. Remote laboratory current set of boards. It includes 10 main boards and 3 replica of 3 different experiment boards performing 12 different experiments on basic electronics plus a singular one (left) which measures the strain-stress characteristic of a polymer sample.

Once a given experiment is selected in the web page, the user gets the remote panel on his computer and takes the control of the LabView application (Vi, Virtual instrument) associated to this specific replica of the experiment. At the beginning, the Vi configures the board to select the circuit by switching relays which is transparent to the user. Then, the user selects the parameter values and circuit configuration (e.g. in the regulated power supply circuit, the filter capacitor and load resistor can be changed between three values each, and the circuit configuration (half/full wave rectifier, regulator inserted or not) can be selected). The main circuit node's signals are depicted in the schematic included in the panel, which can be monitored in three ways: instantaneous value, time series and graphical representation. In the first view of the panel, all signals are represented together. The individual signals can be seen more detailed (autoscaled) by scrolling the panel.

The didactic experiment guides include several documents: the experiment background review, the panel's user manual, the suggested set-up and a set of questions that student should answer using the obtained results. Usually, the student should paste these data to spreadsheet program to perform calculations (e.g. power from voltage and current, determination of slopes, etc.). At the end of the didactic guide, there is a set of additional questions.

III. PILOT EXPERIENCE

Seven High Schools from around Catalonia were selected and their Technology teachers were contacted. The amount of students of their Technology subjects in the two last years of High School was around 100. All of them were invited to visit the physical laboratory that supports the remote experiments in a specific Telecom BCN School Open Doors day. This was a good activity, useful not only to increase the feeling of reality of the remote lab but also to show the students the School laboratories and facilities and even the research activities. During the last term of year 2008, they performed classes based on the remote lab, mainly using two modalities: taking the whole group to the computer room and carrying out the experiences described in the didactic guides or using the experiments as demonstrators in the classroom using a projector (Figure 4).

Figure 4. Students using the remote lab as demonstrator in the classroom in their High School

Not all the High Schools performed all the experiments, but they were asked to present the reports they made to a contest. The first, second and third winners received an award consisting in a technological gadget.

At the end of the term, the teachers and students were asked to fill a survey through a web page. The survey contained eight questions with a quantitative answer (1-low to 5-high) and five questions with an open, written answer. Table I shows the marks given by the first 8 questions. The experience was well valued, mainly by the teaching staff, as it could be expected.

TABLE I. RESULTS OF THE SURVEY

#	Question	Std.	Teach.
1	Ease of use	3,4	4,3
2	Appreciation of the experiments	3,7	4,3
3	Appreciation of the documentation	3,8	4,5
4	Is this resource useful to improve the experimental learning?	4,0	4,5
5	Appreciation of the remote lab as an innovative resource	4,0	4,5
6	Perspectives of future	4,0	4,5
7	Personal satisfaction	3,6	4,5
8	Global appreciation of the remote lab	3,9	4,5
	Average	3,8	4,45

Concerning the qualitative answer questions, their responses were grouped by similarity. The most representatives are the following:

Q1. Which is the aspect that you consider more positive and practical of the remote lab?

- Being able to work in teams in a different way than usual.
- Being able to see the graphical results in real time during the class.
- The feeling that what you are simulating is really there and the fact that is not virtual, nor calculations.

Q2. Which is the aspect that you consider more negative and less effective of the remote lab?

- The limitation of a single simultaneous user in some experiments.
- The fact that the pilot experience has been performed at a point in the course which was not the most suitable.
- The limitation of getting only a limited set of values of a few variables.

Q3. Which aspects can be improved?

- An increase in the number if simultaneous users.
- The experiments should have a higher number of parameters to be changed.

- The aesthetical aspects of the panels, the availability of the lab, the extent of the documentation.

Q4. Suggest please new experiments:

- Digital electronics and experiments on other technological fields (mechanics, hydraulics, robotics, magnetism…).
- Experiments with continuous changes in the parameter values, i.e. not only a few discrete values for the resistors.
- Measurement of voltages and currents in more complex DC circuits. AC and transient measurements in RLC circuits.

Q5. Global comments:

- The experience has been positive both for the students and teachers. It has improved the student's attitude.
- It has helped to reinforce the theoretical explanations.
- The experience is innovative and should be improved and augmented in the future

IV. Current work

Several tasks have been carried out this last year and a lot more are under development. The whole laboratory was moved to a more suitable location and the software was transferred to a new and more powerful server. An IP camera is connected in order to have a visual confirmation of the experiences, even when the only mobile part is the strain-stress experiment. At the beginning of year 2009, the lab received a grant from the Catalan government, together with other experiences that should increase the scientific and technologic vocations. Thanks to that, new experiments are being developed: a robotic arm whose movements can be programmed in real time or following a sequence, an hexapod robot based on shape memory alloy (*Stiquito*), an experiment to measure the efficiency of different lamps, an experiment to visualize the spectra of different light sources, … Also more replicas (5) of the existing experiments are being built. Given that users can hold the panel's control for several minutes but in fact the real usage of the hardware resource is short (usually of around 10s periods), we are developing "virtual replicas", which allow sharing a given board between several panels, using concurrence and event control.

More complete software it is under design to manage the secure access and the resource organization for large groups. It also includes a resource booking tool to allow teachers to book a full set of experiments for a given slot of time. In addition, there is a control layer which manages the dynamic creation of remote panels under demand and the dynamic assignment of hardware boards to these panels. At this time, iLabRS is currently working and several High Schools are using it. A second promotion campaign will be carried out in January 2010, when the current improvements are planned to be finished, tested and validated.

V. Conclusions

An existing, modular platform to build remote laboratories at the Telecom BCN Engineering School has been used to implement a remote laboratory oriented to Secondary School Technology subjects. The main aim was to increase their technological knowledge and skills but also to promote the interaction between the Secondary Education students and teachers and the University. Thirteen different experiments were implemented and a pilot test was carried out with around 100 students from 7 High Schools. The results have allowed us to face a second phase, with improvements in both the experiments and the control software. The users' evaluation of the experience was clearly satisfactory.

Acknowledgment

Francesc Garófano has devoted a sabbatical year paid by the Education Department of Generalitat de Catalunya to develop this project. The second phase of the project has a grant from EnginyCAT project, SOC-FSE. The authors wish to acknowledge all people that have worked in this project and the teachers and students who have taken part in the pilot experience.

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SecondLab: A Remote Laboratory under Second Life

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Abstract—**The present work describes the implementation of a new remote lab, SecondLab, that allows students to control a microbot from Second Life. SecondLab works over WebLab-Deusto, the remote lab of the University of Deusto, giving the students the chance to work with real experiments from a social 3D-based immersive environment. This approach places the remote lab closer to the students, trying this way to increase their motivation to study science and engineering.**

Remote experimentation; Second Life; e-Learning

I. Introduction

The new learning trends suggest both entertainment and highly immersive environments as a way to achieve an effective learning process. In particular, socialware and game-like implementations are presented as attention-captive solutions applied to virtual education [1]. The recently published research from the Massachusetts Institute of Technology focused on Physics experiments is a commendable example on this direction [2].

The present work follows this line proposing a tool that can contribute to solve the current decrease of enrollments in scientific and engineering-related degrees. To achieve this purpose, SecondLab takes advantage of the technical possibilities of remote labs and the increase of popularity of social immersive environments among teenagers.

The present paper is structured in two main sections. Section II first shows an overview of the projects involved in the design, while Section III describes the implemented solution from a technical point of view. The research finishes in Section IV with the conclusions and future plans.

II. Background Components

The aim of this project is to offer an attractive electronic experiment to be used from a virtual 3D environment, taking advantage of other projects with different well-defined goals. Pursuing this aim, the research has basically involved an integration effort. The three components which SecondLab is based on are WebLab-Deusto, Second Life and the SecBot microbot (see Fig. 1).

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Figure 1: The three background components

A. *WebLab-Deusto*

WebLab-Deusto [3] is the remote lab of the University of Deusto, which makes possible to offer real experiments to a certain group of users through any computer network, such as Internet.

This remote lab has been used since February 2005 by the students of the University of Deusto as an essential tool for their practice works in four different engineering-related subjects.

WebLab-Deusto provides a distributed software architecture (see Fig. 2) that makes easy to integrate new experiments inside, so every experiment served this way automatically takes advantage of all the common features implemented by WebLab-Deusto:

- *Authentication*. WebLab-Deusto offers an extensible authentication system that currently supports three ways to verify the user credentials: username and password stored in a MySQL database, authentication through a remote LDAP server and trusted authentication based on the IP address of the client that is trying to log in.

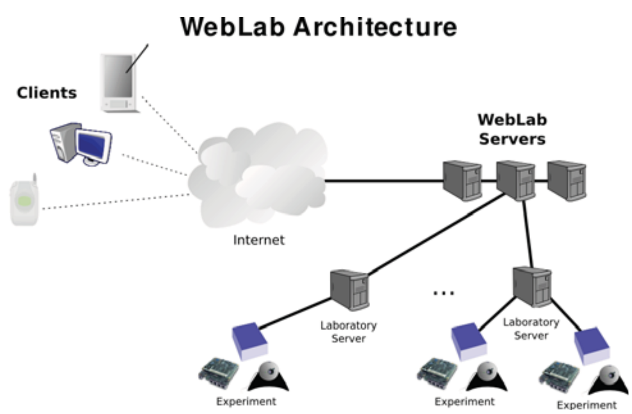

Figure 2: WebLab-Deusto architecture

- *Reservations*. WebLab-Deusto offers a generic reservation system that makes possible to reserve any available experiment for a non-scheduled period of time (i.e: 200 seconds), which is defined as a parametrizable experiment-dependant property.
- *Queue management*. WebLab-Deusto manages different reservation queues for the different available experiments, making the experiments themselves completely unaware of the users that are trying to use them.
- *Scalability*. The WebLab-Deusto architecture is horizontally scalable since more hardware can be added to improve not just the performance but also the availability of the remotely served experiments. The more experiment hardware devices of the same type are added, the more users will be able to use the same experiment simultaneously.
- *Security*. The WebLab-Deusto distributed architecture keeps in isolation the experiment-dependant hardware and software, so any problem related to a wrong use of the experiment will never put the whole remote lab at risk. Besides that, this same architecture considers the Login server separate from the others, so the most sensitive information (usernames and passwords) could not be accessed in case of eventual security attacks (see Fig. 3).
- *Deployment*. The WebLab-Deusto deployment system makes easy and flexible to configure the distributed network map in which all the servers and experiments are involved. Every WebLab-Deusto server can be configured with an easy-readable .xml file to declare the protocols which it will be communicated through, being five different ones available up to now: XML-RPC, Python-dependant SOAP messages, TCP sockets, UNIX sockets and “Direct” (direct method calls inside the same program instance).
- *Logging*. Everything that may happen during the use of the remote lab can be logged at different risk levels. The amount of events to log is up to the WebLab-Deusto administrator.

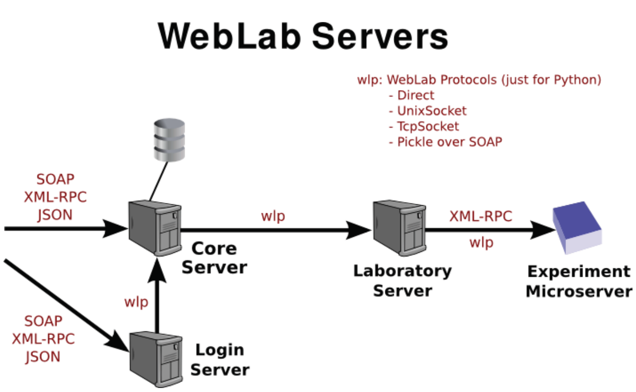

Figure 3: WebLab-Deusto servers

- *Administration*. As a common feature that every remote lab requires, WebLab-Deusto offers administration tools that make easy both to monitor who is currently using the remote lab as well as to add, edit or remove users, permissions and experiments.

B. *Second Life*

Second Life [4] is an end-user MMOW (Massive Multiplayer Online Worlds) software developed by Linden Lab since 1999. It provides a 3D environment where people can create their own customized avatar (a virtual representation of a person) and interact with other people. Its goal is to offer a real-world-like platform with the same physic laws, rules of conduct and opportunities (to get a job, to buy things…) that everybody has in the real life.

The most remarkable feature of Second Life is that there are no established goals for its users. Due to this, the platform has been mainly used in an entertainment way, but during the last few years it has also been used as an educational tool [5].

Second Life consists on two main software components: the private server farms at Linden Lab and the free-software client. The servers manage the business logic and the persistence tier, so the client is just responsible for rendering the 3D world and notifying the servers all the events carried out by the user. Therefore, developing software in Second Life entails both designing 3D graphics as well as programming server-side software.

C. *SecBot*

SecBot is an auto-programable microbot specifically designed for this project. Despite that, SecBot can be considered as a background component, since any other experiment could have been offered in SecondLab instead (from a technical point of view) and the microbot itself could also be used in a different context.

The reasons for choosing a microbot as the experiment offered in SecondLab are both educational and technical. The educational reason points to the attractiveness of the experiment for young students, which works in the direction of promoting entertainment while learning. The technical reason is related to the state-of-the-art in auto-programmable microcontroller memories. Now it’s possible to create an autonomous microbot with the capability of programming its own instructions memory, so it can completely change its behavior in run-time. This is exactly the feature required to design the autonomous remotely-programmable microbot desired for the educational aims of the project.

This customized microbot, called SecBot, has been built over the *Robot Sumo Terminator S300230* from SuperRobótica [6], a commercial mechanical structure commonly used in the fighting modality of robotics competitions. As a first prototype version, SecBot offers the student the following components:

- 1x PIC18F4520 microcontroller from Microchip [7]
- 1x MD22 engine controller circuit from Devantech [8]
- 1x GP2D12 infrared sensor from Sharp [9]

III. SECONDLAB

SecondLab merges all the previous components in order to create a remote lab that allows students to program a microbot from Second Life. The best way to understand how SecondLab works from the student point of view is looking at the “happy path” scenario, described by the following steps:

1. Write a C program with the instructions that the microbot shall follow.
2. Compile the .c file to obtain the assembler .hex version of the program.
3. Open Second Life and log in with the avatar’s name, surname and password.
4. Travel to SecondLab by typing “SecondLab” in the search tool.
5. Enter the laboratory with the avatar (see Fig. 4) and press the big green START button.
6. Upload the .hex program (see Fig. 5).
7. Wait until the screen in front shows the microbot working under the programmed orders (see Fig. 6).
8. Press the big red STOP button and leave the laboratory.

A. Architecture

Since SecondLab takes advantage of the previously described background components, its architecture is completely determined by them. In particular, WebLab-Deusto determines the global architecture, as it is the real remote lab underneath.

The WebLab-Deusto architecture follows an experiment-agnostic approach [10]; that is, it makes all its features completely independent of the specific requirements of the remotely-served experiments. Thus, integrating a new experiment in WebLab-Deusto becomes as simple as developing two components: a microserver at the very end of the server side (capable of interacting with the microbot), and a web-client module at the highest layer of the provided web-

Figure 4: The SecondLab entrance

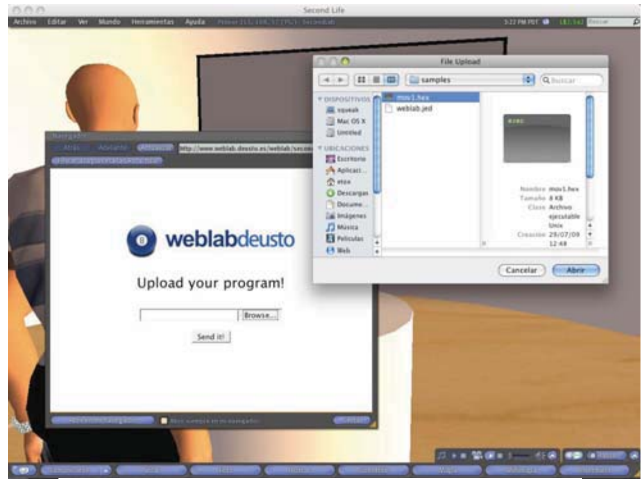

Figure 5: Uploading the program

client application (presentation layer). Since the client platform had to be Second Life in this project, the most remarkable challenge became making Second Life work as a WebLab-Deusto client. Figure 7 shows the interaction among all these components.

A third smaller component, Web-uploader, had to be developed too in order to solve a certain Second Life technical limitation that will be explained later.

B. Microserver

The function of a WebLab-Deusto microserver is to communicate the experiment-agnostic set of WebLab-Deusto servers with the final hardware of the experiment (the SecBot microbot in this project). The only requirement established by WebLab-Deusto to develop a microserver is to implement the following interface (neutral language):

- test_me(value)
- start_experiment()
- send_file_to_device(file, file_info)
- send_command_to_device(command)
- dispose()

This interface can be implemented in any of the following supported protocols:

- Direct (function calls from/to the same process)
- Pickle over UNIX Sockets (Python dependent)
- Pickle over Internet Sockets (Python dependent)
- Pickle over SOAP (Python dependent)
- XML-RPC (language independent)

As figure 7 shows, the microserver in this project had not just to translate the messages received from WebLab-Deusto to the microbot, but also to manage with two different communication protocols: Bluetooth and any other from the

Figure 6: Watching the microbot working

five above. For this reason, a high-level and well-communicated language as Visual Basic .NET was chosen to develop this component. Therefore, XML-RPC was the only possibility to implement the listening interface.

C. *Client*

As previously explained, the most significant challenge in this project was to make Second Life work as a WebLab-Deusto client. Since Second Life provides a generic world where people can live and build their lifes, it also provides technical features so developers can program the created objects and buildings with certain behaviors.

Several steps must be followed to develop a custom piece of virtual world in Second Life. Building is not allowed for free, so buying a plot of land is the first step in order not to lose the work; secondly, every desired object must be graphically designed (buildings, items, textures…) using the 3D model editor provided by Second Life; and lastly, as many programmed behavior as wanted can be added to the world thanks to the scripting language created by Linden Lab (*LSL, Linden Scripting Language*). Every object in the world can be linked with many LSL scripts, which will be executed when the different programmed events happen in the virtual world (e.g.: an avatar touches a certain object).

From this scenario, developing a WebLab-Deusto client in Second Life entailed two big steps: designing a graphical 3D laboratory where the students could go with their avatars and communicating this laboratory with the remote lab so it could work exactly as a valid WebLab-Deusto client. Since the graphical task involves a creative work, the technical challenge was programming a communication layer under the conditions of a limited language like LSL.

The WebLab-Deusto architecture presents the server side as a webservice with the following public interface facade (neutral language):

- login(username, password)
- login_based_on_client_address(username, address)
- get_user_information(session)
- list_experiments(session)
- reserve_experiment(session, experiment)
- get_reservation_status(session)
- send_file(session, file, file_info)
- send_command(session, command)
- poll(session)
- finished_experiment(session)
- logout(session)

This facade can be called using any of the three following format protocols:

- SOAP
- XML-RPC
- JSON

Second Life offers both XML-RPC and the underlying HTTP protocols; however, the provided XML-RPC support is too limited to be used with a minimally complex service (only one integer and one string values can be retrieved at a time). Therefore, an XML-RPC layer has been manually implemented in LSL so the provided HTTP service is definitely used to communicate Second Life with WebLab-Deusto. This developed XML-RPC layer is limited to the specific use done in this project, so it cannot be considered a generic XML-RPC library for LSL. Although the original design considered it, the technical memory restrictions found in Second Life (64 KB/script including bytecode, stack and heap) made impossible that desirable approach.

Finally, as figure 7 shows, the communication between Second Life and the webcam that points to the microbot is done through the RTSP streaming protocol, thanks to the easy-to-use RTSP client support offered by Second Life, which only requires to specify the URL where the streaming is received from. The network camera used in SecondLab is the D-link DCS-5220, although any IP-based webcam with RTSP support could be used.

D. *Web-uploader*

The web-uploader server module covers a Second Life limitation. The LSL programming API does not offer any user interface component to allow the user to select a file from its computer. This shortage becomes a critical issue in a project

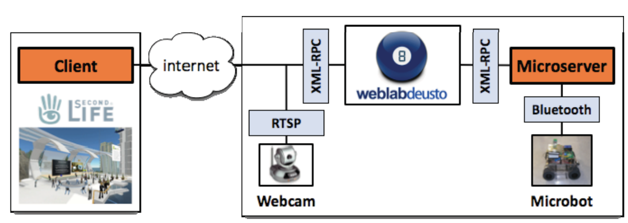

Figure 7: Architecture of SecondLab

like SecondLab, where sending a file from the student's computer is the main action in the interaction scenario.

This module takes advantage of the most flexible utility offered by the LSL programming API, which is a function that shows an embedded web browser with the specified URL loaded. The solution has been developed like a set of two server-side Python scripts. The first one offers a traditional HTML form with a *file* field that allows the user to choose a file from its hard drive (see Fig. 5). As figure 8 shows, when the submit button is pressed, this script sends a HTTP POST request to the second one, which really sends the selected file to WebLab-Deusto and notifies Second Life that the file has been sent, so the web browser can be closed and the user can be told to look at the virtual screen in front.

IV. CONCLUSIONS AND FUTURE WORK

SecondLab proves that it is possible to mix virtual environments with real experimentation in a first approach (prototype version). However, it also proves that developing a remote lab for end-users under Second Life is not recommended due to its serious technical limitations:

1. *Limited scripting language*. The Linden Scripting Language is not comparable with any modern programming language. Its most remarkable handicap is the limited support offered for data types, which makes impossible to manage minimally complex data structures in memory. Suffice it to say that LSL does not offer basic structures (struct in C) or dictionaries, being a very limited (non-nestable) list the most complex structure supported.
2. *Few User Interface components*. Second Life was not designed as a real development environment but as a platform where average-users could create buildings and interact with other avatars through simple question-answer dialogs. Therefore, the LSL programmer can only get input data from the user by two simple UI components: a dialog window with customizable answer-buttons (llDialog) and a text box where the user can write characters (llTextBox). As already explained, sending the user's .hex file in SecondLab had to be implemented using the embedded browser provided by Second Life in a quite unorthodox way (see Fig. 8).
3. *Memory restrictions*. Every LSL script is only provided with 64 KB of total memory (bytecode, stack and heap included) at the Linden Lab servers. Having tested during the development of this project that 1000 lines of LSL source code consume approximately 55-60 KB of memory, this restriction becomes a significant problem that makes Second Life a really limited environment where almost none ambitious project can be developed at. However, Linden Lab also enables to set up a personal server and connect it to their grid, so the environment restrictions imposed by the Linden Lab service might be avoided. Although SecondLab has not been deployed this way (since renting a land was enough for a prototype), this other approach may solve the memory limitations.
4. *Lack of high-level communication protocols*. As already said, although according to the documentation LSL offers both XML-RPC and HTTP as communication protocols, the provided XML-RPC support is too limited to be used with a minimally complex service. Therefore, HTTP becomes the only well-supported communication protocol, so any higher-level one must be manually implemented (as done with XML-RPC in this project).

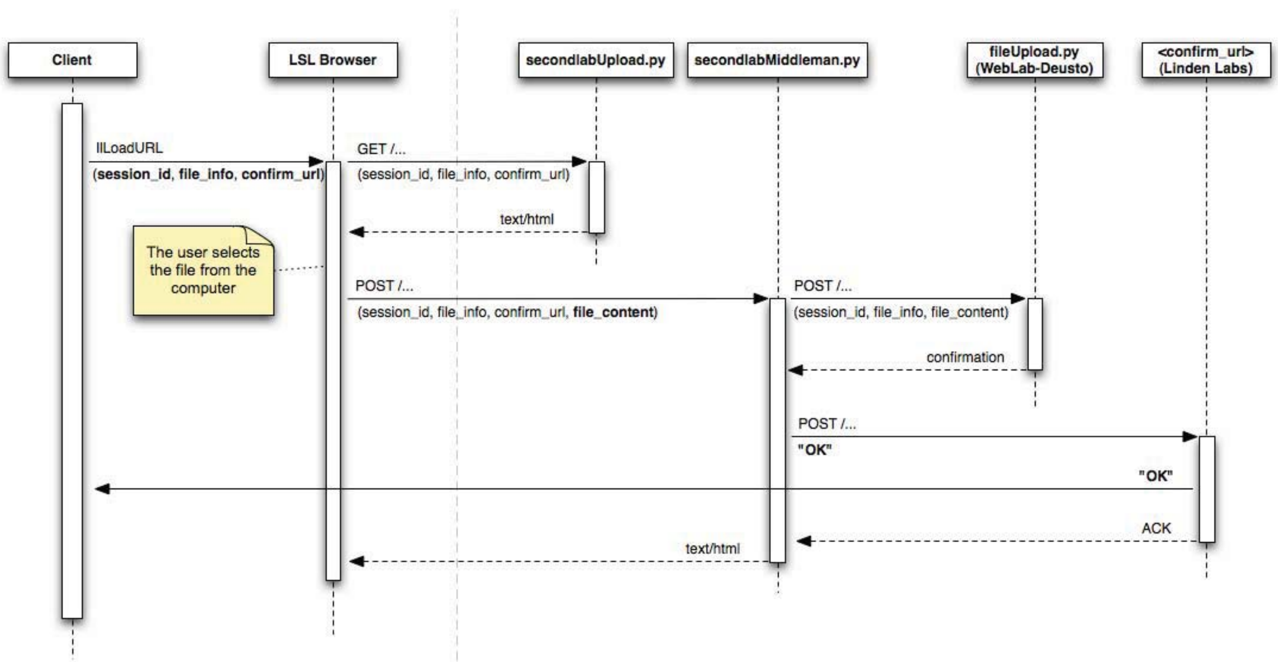

Figure 8: The web-uploader sequence

According to these limitations, a production-ready 3D-based remote lab for end-users should consider the idea of choosing a different 3D environment, such as Wonderland [11] or OpenSimulator [12].

After getting around of the current Second Life issues, future plans for this project consider technical improvements both in the software and hardware sides.

The main software improvement will extend the functionality of the remote lab (based on Second Life or any other 3D environment) to offer two real microbots for two students at the same time, so different kinds of competitions may take part remotely in order to increase the students motivation.

In addition, the next SecBot version will rely on an auto-rechargeable battery system, so the microbot will be completely autonomous. This mechanism will be based on a circular customized ring. The walls of this ring will be filled with two conductor strips connected to the power supply, so as the microbot stops being used it can move forward and stay attached to any wall charging its battery.

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Hardware Implementation of Remote Laboratory for Digital Electronics

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Abstract— **This short paper presents a new hardware system that lets develop labs of Digital Electronics. The system is focused on the verification of logic functions, so teachers can create new experiments only changing the problem proposed, within the range of input variables and output functions that system supports. The students have to solve the problems finding and simplifying the functions. Then, they must implement the results in the proposed system.**

Keywords - logic design; laboratories; practice assesment

I. Introduction

This paper shows how an experiment about realization of logic functions using logic gates can be performed with a flexible, computer based hardware. This system is initially designed for used in remote labs, but can also be used “in-situ” for normal labs.

This work is a demonstrative part of the Project S-Labs “Open services integration for distributed, reusable and secure remote and virtual laboratories”, sponsored by Spanish Ministry of Education and Science. The main objective of this Project is to integrate technologies for learning theoretical and practical using any Learning Management System (LMS) [1].

The proposed system has several characteristics that make it different from other existing remote laboratories.

First, the experiments can be performed using the services offered by the LMS used by any University involved in this project. Then this remote laboratory will be a new resource, like other material published in Digital Electronics Courses over the LMS’s. With this feature we don’t need to create again the basic services that a remote laboratory uses, like administration, content packaging, etc., because they are included in all LMS.

For teachers, has the advantage of being able to share the laboratory between different departments or Universities, with little investment and, of course, a sharing policy. Then the system can be fully productive.

For students, the main advantage is the use of the familiar environment provided by the LMS, so make remote practice becomes easier.

On the other hand, the second important feature is that the system allows the realization of logic functions without restrictions, so you can perform many different practices. With few changes you can prepare different experiments for different groups of students, or you can change the remote practice from one course to another, avoiding that student’s lab results could be passed on to “next year” students [2].

In the following paragraphs of this paper will be listed the objectives to be achieved with this laboratory and the physical description for the elements of the system.

II. Objectives

The main objectives of this work are:

- Get flexible and reusable systems for remote labs.

  The laboratory proposed is very flexible: the professors of different courses can implement different practices even at the same time. Also the system can be used for other kind of practices, for example to check a given logic function or to study maxi- and miniterns.

- Enhance the students’ skills in logic design.

  With this tool the students can test any function they obtain in the problems that the professor proposes. They can test their solutions in real hardware with real results, instead of simulations.

- Enable the students to control the experiment.

  There are remote labs that are like “black box” for the students. We try to show them all the process involved in the experiment, and avoid any component that can be difficult to understand for beginners in Digital Electronics.

- Get an adequate use for the remote labs.

  If the equipment needed for the remote lab is used only by one group of students in a University, the ratio between material and personal cost and use of laboratory is poor, because it will be used only one or two weeks a year. Sharing the lab between several courses and Universities will increase this ratio.

- Get a cost reduction in remote labs.

  The equipment needed for a remote lab can be expensive [3]. In this approach, we use elements that can be achieved at an affordable price.

III. Description of the System

To achieve the objectives listed below, we are developing a hardware set and the computer programs needed for the control of the hardware. The system is an evolution of another one developed to teach practices "in situ" [4]. The system is a useful tool for the students, which have the opportunity to experiment with digital circuits outside of the laboratory. In the following paragraphs we explain the hardware components and the software programs needed to build this new laboratory system.

A. Hardware set

The physical system has four main parts. In Fig. 1 you have a block diagram of the whole platform:

- A computer.

  The main tasks for the computer are the control of the correct performance of practices and the lab server. It receives the logic function to be performed, set up the function board which will be described in the next paragraph and sends back the functions results.

  The computer selected for this purpose has special specifications. Thus, being a computer that will operate 24 hours a day must have reduced power consumption. On the other hand, a small and low-cost computer will be the better option.

  We have chosen for this remote lab a mini-ITX mainboard [5]. The Mini-ITX form factor (just 17 cm x 17 cm) is designed to fit in the mounting points of a standard ATX board, enabling to use a standard case to fit all the system components. The Mini-ITX embedded boards are used on a variety of applications: in-vehicle computers, digital kiosk and advertisement, Network Attached Storage (NAS), etc. The main features of these boards are: X86 architecture, low power consumption, rich integration (LAN 10/100, USB, Serial, ATA, SATA, PCI connections, etc.). For our purposes, the most important are the consumption and the USB and PCI connectivity. We used a fan less VIA EPIA 6000 board with a Compact Flash based Solid State hard disk for storage, giving a reliable and cost effective platform without mechanical parts.

- The function board.

  This is the circuit that performs the logic functions. It's based on LSI integrated circuits, and its main parts are an AND gate array followed by an OR gate array, with programmable connections between the two arrays, and also between inputs and the AND array. The state of the switching matrix is stored in a memory builded with shift registers that control directly the switches. Fig. 2 shows the diagram for this board. This configuration for a circuit that performance logic functions is intuitive, because is like the wire diagram that students can write. We prefer this more complex approach instead of the use of a field programmable gate array (FPGA) because the FPGA is like a "black box" for the student, and its more complicate layout probably will be inaccessible for beginners. In addition, the use of FPGA forces students to make programs that probably needs more knowledge of digital electronics that they have. With this circuit you can generate a modest performance: up to 4 functions of 4 variables each, sufficient for the most of the practices.

- A digital acquisition board.

  This board has two different tasks. First, the card programs the logic functions to be performed in the function board, putting into the memory the switch configuration. Second, several of his digital lines enters the values of the variables into the function board and others read the generated functions and send the results to the computer.

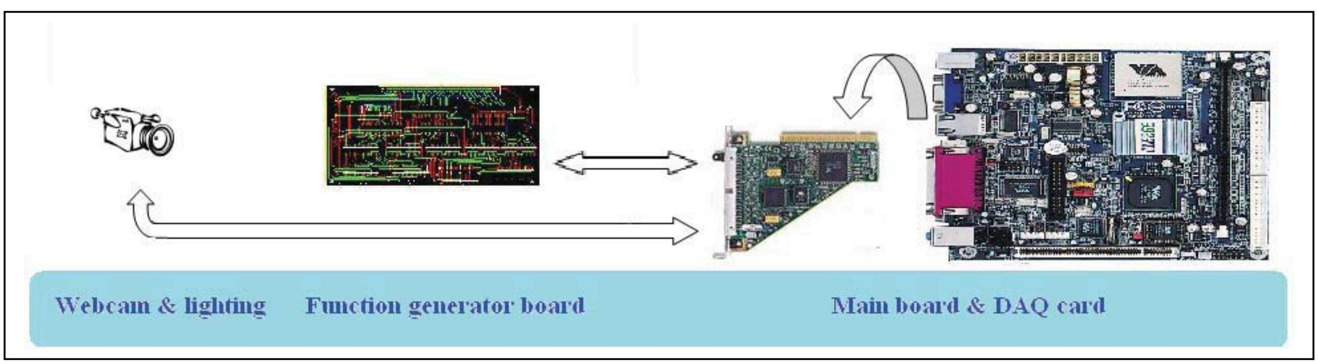

Figure 1. Block diagram for the hardware.

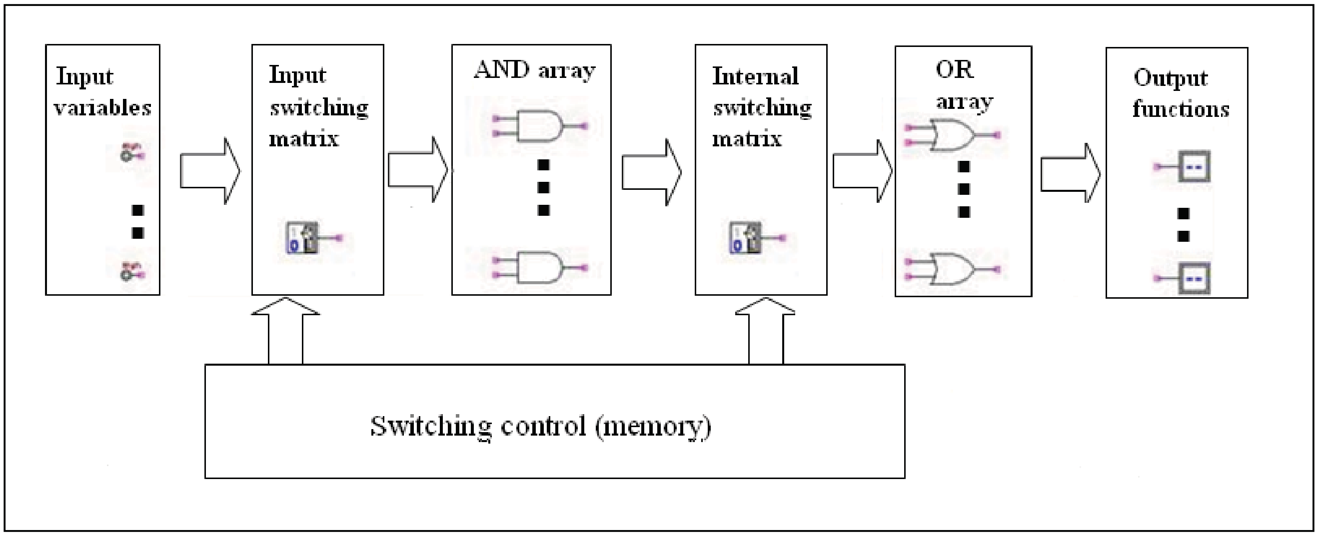

Figure 2. Block diagram for the function generator card .

For this prototype we have chosen a NI-PCI-6503 acquisition board from National Instruments [6]. This is an acquisition card with 24 digital input/output lines organized in three 8 bit ports, and PCI connection to the computer. The board is in the basic range for this manufacturer, and its price is low compared with other solutions. For our purposes, one port is used as output and sets up the four variable values, other port is set up as input and his four lower bits reads the functions results and in the last one several bits are set up as output to put the switch values into the memory and others act as inputs for handshaking.

- A webcam.

The webcam is used to receive visual feedback from the function generator circuit. The circuit has LEDs for inputs and outputs. A view of the circuit lets the students check out the state of the variables and functions. There are no moving parts in the circuit, and the changes on the LEDs state are slow, so a rate of one frame per second is enough for our purposes. The webcam have extra illumination with LED lighting that only goes on when an experiment is running.

All these elements are housed in a desktop PC case, so that the laboratory is a compact set well isolated from ambient light interference and possible mishandling. Figure 3 is a set of pictures of this prototype.

B. Software

If we want to run this lab in a remote way, we need two software applications. This paper is really focused on the hardware, but it is necessary to point out some aspects of the software.

The server software application is now under first stage of development. The main tasks of this software are:

- Receive the functions to be performed. The format used for the functions representation is a vector containing all the variables and its opposite, e.g. A and $\overline{A}$, being $\overline{A}$ =NOT (A). If a position have a

Figure 3. Photographs of the prototype.

"1", the variable is present, if have a "0" not. An example could be the following function:

$$F = B\overline{C} + A\overline{B}C + \overline{A}D \quad (1)$$

That can be represented as:

$$F(ABCD\overline{A}\overline{B}\overline{C}\,\overline{D}) = 01000010$$
$$10100100 \quad (2)$$
$$00011000$$

- Program the switches. The software takes the vector representation, like the example shows in (2), and programs the switching matrix according to the function. Every value of an element of the vector is an input switch, and the number of elements of the vector determines how many internal switch will be closed.
- Put input values on the variables. Once the functions are programmed, the user can select one input variables combination to be sent to the function, and the software will put these values in the function generator card inputs.
- Take output values of the functions. The acquisition card reads the results from the functions implemented in the function generator card and sends to the user for verification.
- Makes the truth table. If it is desired, the software can build the truth table for the functions.

This software has been developed in Labview environment [7] [8]. This developed software kit allows an easy communication with the DAQ card, and has been used in older similar projects [4].

The software can add new features to improve the system, or even to change its functionality. For example, with a new version of software we can transform the remote laboratory in an "in situ" laboratory. With this example version, the students could build the switch matrix by themselves selecting in a schematic view of the function generator board the state of all the switches.

On the other hand, the remote laboratory needs to be connected to one or several LMS to be useful for students. This feature can be achieved if we define, design and develop a middleware capable of communicating an E-learning platform with the laboratory, as shown in Fig. 4. The LMS environments arise as distributed systems and must operate in real time processing of data from heterogeneous systems, databases, directory services and applications, and integrate with other environments. To be able to integrate all these pieces is necessary an universal medium, neutral with regard to the platform, to describe, transport and transform data between distributed systems: XML. Using XML as a standard representation would develop multiple types of interfaces based on other technologies such as AJAX or dotNET that have interactive components lighter burden in terms of their own Java applets.

IV. AN EXAMPLE OF USE

With the system proposed, the students can check their knowledge for solving problems that involve digital logic. The professors will put on one or several LMS's courses problems about logic design. When a student access to the LMS's course, there will be two links, at least, along with other LMS services (chats, forums, contents of course, etc.). When the students click on the first link a proposed problem will be shown in a frame of an LMS. Then he will have to find the relationships between variables and functions and to obtain the corresponding truth tables. Finally, he will have to simplify the

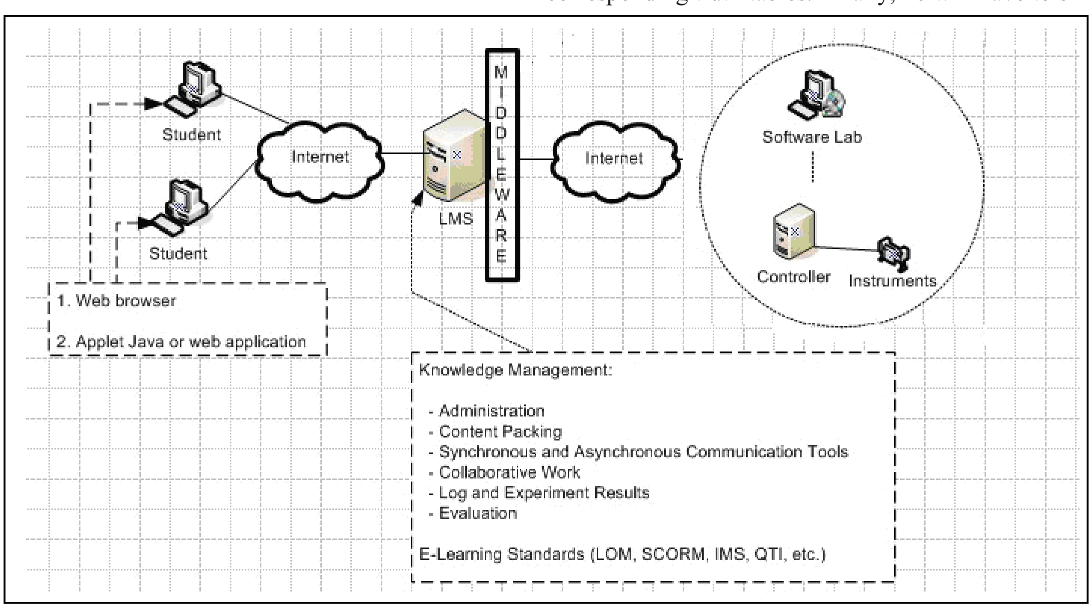

Figure 4. Integration of LMS with remote laboratories.

functions using any method (e.g. K-maps). Once the problem is done by the student, he goes back to the second link and the student can enter the remote laboratory through LMS`s course and intro the functions obtained. A comparison between the truth tables obtained and the ones offered by the remote laboratory will be the final result of the experiment. The log file of the sessions helps the professors to evaluate the student skills. It important to say that the students beside of working with the problem and the remote lab, he can use the services offered by LMS as chats forums, etc.

V. CONCLUSIONS

A remote laboratory developed to check digital functions has been presented. At this moment, only hardware is on an advanced step, therefore not been possible to obtain results of its application in a group of students.

The main features of this approach are:

- It's a laboratory designed for use inside any LMS.
- It's a low cost, low power consumption system.
- Simplify the implementation of truth tables.
- It's very versatile.
- It can be used "in situ" only with a new software development.
- It's open to future developments.

VI. ACKNOWLEDGMENTS

This work has been developed inside the framework of the S-Labs ("Open services integration for distributed, reusable and secure remote and virtual laboratories") Project, supported by the Spanish National Plan for R&D (2008 – 2011) of the Science Ministry. Our thanks to all the people involved in this Project.

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Session 02E Area 5: Lifelong Learning and Nontraditional Students - Theories and Courses

Knowledge Management and Professional Profiles in Electronic Systems Engineering

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Scientific project management course introduction in doctoral studies in Riga Technical University

Galkina, Alina; Kunicina, Nadezhda; Ribickis, Leonids

Riga Technical University (Latvia)

Introduction to Electronics as a Minor Subject

Winzker, Marco

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Role of Faculty in Promoting Lifelong Learning: Characterizing Classroom Environments

Chen, John C.; Lord, Susan M.; Nottis, Katharyn; Prince, Michael; Stefanou, Candice; Stolk, Jonathan

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Knowledge Management and Professional Profiles in Electronic Systems Engineering.

The Function of University-Industry Collaboration

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Abstract— **This paper presents a work in progress related to the knowledge and competence management techniques applicable in an electronic systems engineering company. It also discusses the role of the university-industry collaboration in the knowledge management process.**

Keywords: knowledge management; engineering education; professional profiling, electronic systems engineering.

I. INTRODUCTION

In this paper we describe a work in progress related to the systematization and organization of competence and knowledge management processes in a small electronics engineering company. This work is promoted by an electronics engineering and consultancy company and conducted in collaboration with the Electronics and Telecommunication Department of the University of the Basque Country. The basic objective of the work is the development of a preliminary analysis that could serve as the basis of a collaborative proposal for a project to be presented in the framework of the regional R&D and innovation initiatives.

II. ELECTRONICS SYSTEMS ENGINEERING

A. Ubiquity of Electronics

Electronics systems are penetrating all possible aspects of human life, and are being used to improve them. Companies seeking to add value to their products are often driven towards the integration of embedded electronics, transforming traditional devices into more adaptive and useful ones.

In the medical field, electronics systems are not restricted to hospitals; they can also help patients, disabled, elderly and dependent people outside medical facilities.

Modern forms of mass transport system, such as trains, airplanes and cars, use embedded electronics technology to increase safety and performance. In the automotive sector, for example, the share of electronic components in the total value of a passenger vehicle is currently estimated at about 25%, with an expected increase to 33-40% in 2010 and up to 50% thereafter [1].

Electronics is an enabling technology for many sectors and fields of application. The existence of a local electronics industry is widely considered to be an essential contributor to prosperity and growth. This is not only due to the scale of market for electronics products, but also to the radical effect that the application of electronics has on the competitiveness of other sectors of the economy. In the Basque Country (Spain), the Association of Industries for Electronic and Information Technologies (GAIA), comprising more than 190 companies, has structured its 2009-2012 strategic plan with horizontal branches (Electronics and communication technologies) crossing three main vertical sectors of application: energy, transport and health [2].

In addition, we cannot overlook the impact of globalization. Offshoring and outsourcing are spreading globally in all economic sectors, but are especially prevalent in electronics, where even R&D activities are being outsourced. Electronic systems must often be assembled from COTS (Commercial off the Shelf) electronic subsystems and components, which may be manufactured half way around the world. But, at the same time, system integration is becoming more complex and involved. One of the big challenges in electronics systems engineering is to manage the complexity and reliability of the development, operation, and maintenance of embedded electronics systems [3].

B. The role of an electronic systems engineering and consultancy company

While companies operating in various sectors consider electronics as an essential technology, in most cases they view it as a means, not an end, in their business strategy. The rapid evolution of technology and the variety of skills and techniques required for a successful application of electronics in their products is driving them to consider outsourcing of engineering as an optimal solution. Even electronics-related companies follow this trend. One can find a UPS manufacturer that sees its real product not as equipment but as the "power availability at the point of service", and therefore, focuses its strategy in setting the specifications and analysis of the application, outsourcing its development and manufacturing.

Other companies have undergone a rapid shift towards electronics technology. Consider, for example, a wheelchair manufacturer, moving from pure mechanical products towards electric wheelchairs that include power electronics, motor control and battery chargers, and, in addition, intelligent navigation and communication aids.

Distributors of electronics components and subsystems are trying to add value to the supply chain. They can offer the range of components needed for a complete solution, from board level components to enclosures, modules and powerful COTS subsystems. They can provide their customers with sporadic technical support through field application engineers. University departments and technological centres should concentrate their resources in research and basic development. None of these actors is orientated towards engineering or consultancy in complex and high workload projects involving demanding quality and deadline objectives.

An electronics engineering consulting company is the link which fills the gap between the end user needs and the available technological solutions (Fig. 1). It uses knowledge as its raw-material (research results and education from universities, internal R&D and collaborative projects with universities and technological centres) or as a semi-finished product (components, subsystems, tools and technologies produced by specialized companies all over the world, or even free software and hardware projects and communities) and generates applied knowledge as its output. Its role is to process and internally manage this knowledge and apply it properly in its clients' projects. To meet its clients' requirements it is essential to use the right type of knowledge, at the right moment in time, and with the right intensity, in every task and during every stage of the project.

The electronics system engineering process follows an iterative loop from the requirements definition, to functional and structural design. The same process is applied in a top-down approach to every subsystem, module or component.

In a typical electronics systems project, a broad range of competences and skills may be required. Managing competencies of the people who need to perform specific tasks or jobs in a project can crucial to the success or failure of the project.

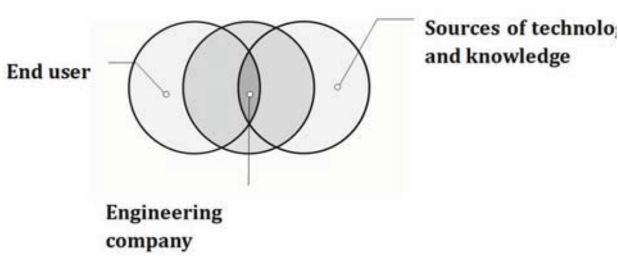

Figure 1. The role of an electronic systems engineering company

III. Professional Profiling based on Competency and Competence management.

In this section we differentiate between competence (the specific level of knowledge, skills, experience, etc. necessary to carry out a defined function) and competency (the description of the knowledge, skills, experience, etc. necessary to carry out a defined function).

Competency and competence management is the process of identifying, classifying and analyzing competencies, and managing competences of the people working in a project. This process must be the basics of professional profiling, selection, hiring, career development, training and evaluation. Core competencies are those key competencies that all members of the organization must master, along with the vision and mission of the company. There is also a distinction between soft and hard competencies (the latter being equivalent to knowledge, skills, and abilities or KSA). In current management and education literature, the structure and management of core and soft competencies has received considerable attention. But, for a small engineering company, the more specific and hard competencies are as much as important as the soft or core ones. This perception is in line with studies that confirm that specific technical competence is the most valued characteristic of an engineer [5]. Our attention will be focused on the structure and management of those hard competencies in the electronics systems engineering.

This work in progress is fundamentally devoted to classification and parameterization. From a static point of view it is a try to establish taxonomy, covering the spectra of skills and knowledge of interest, with fine grain definition, analyzing detailed and very specific skills.

As an example of static classification requirements, it can be mentioned the case of single board computers (SBC) related skills. The static competencies classification must include from the fundamentals of computer architecture to the most specialized and detailed skills, such as the ones related to very specific form factor standards.

From the dynamic point of view, the skills and competences should evolve to adapt to market and client needs. The classification should include parameters to allow analysis of the dynamics, predicting the need for taking actions in order to control the evolution.

Some other examples can be considered to see the importance of this dynamic consideration. In fewer than ten years, a specialist in power supply and power converter design, has had to evolve from a profile involving important design related skills towards a new profile involving specification, selection and verification of converter modules, designed and manufactured by OEM suppliers. Now the engineer has to focus on the study and analysis of standards applicable to the sector. The new profile would be more systems engineering oriented. The impact of offshoring with its cost reductions and standardization of power converter modules has greatly reduced the need or advantage of home-made designs.

As a second example, the case of a microcontroller specialist can be considered. From development with small 8- o 16-bit microcontrollers, programming in assembler or C language, the engineer has had to move towards development with SBCs based on powerful ARM or x86 embedded processors, running RTOS (real time operating systems) or embedded Linux. The new professional needs now to be knowledgeable about driver development and the integration of applications combining compiled and scripted languages, network services, etc

Being able to predict those changes and quickly conforming to them is critical for a small engineering company, which must adapt with agility to new market circumstances and customers, sometimes in very demanding sectors, such as transport or energy.

Our work is currently focused on the development of a software platform for skills and competencies classification. The classification follows a tree structure, with fundamental branches (analogue and power electronics, digital, computer science, communications and networks etc.) split into more specific and specialized branches so that the classification of competencies related to projects and sectors of current interest is prioritized (Fig. 2).

There is also a need to decide the parameterization of every skill related field. Regarding the competence level, classic classifications based on Bloom's taxonomy or the Anderson variant, competence levels of Dreyfus professors [6], and previous experiences [4][9], like the ones applied in clinical practice[7][8] are being considered.

The static tree classification with competence levels has to be graphically analyzable, yielding at a glance the specialization profile for a professional, a team or project requirements. The dynamic parameterization must be also easily analyzable, both for forecasting and for assessment of professional recycling programs. A spectral representation similar to the that used in engineering and physics, indicating the difference between "low frequency" skills (those fundamental skills that are very permanent and are only slowly renewed) and "high frequency" skills (those achieving obsolescence quickly or that have to be acquired and renewed frequently) is proposed.

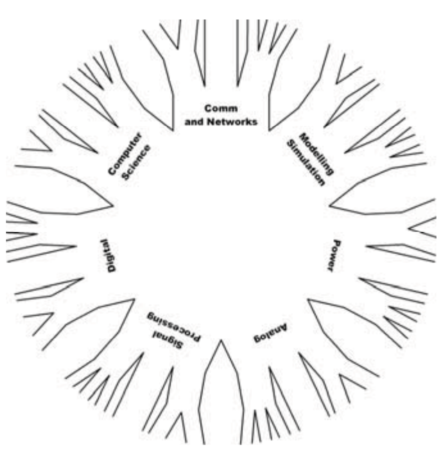

Figure 2. The competency tree

IV. Knowledge Management

The approach to knowledge management (KM) is from the eclectic point of view of engineers approaching any management fad [10][11]. KM has raised strong interest in the business community, but perhaps some managers are thinking about KM as the magic solution that will allow a company to keep engineer's brains after they leave. For us, an important aspect of KM is that the effectiveness of an engineer performance, key of any success, depends on the proper delegation of intellectual tasks and authority to knowledgeable and empowered professionals [15].

Nevertheless, for a company dealing with complex and multidisciplinary projects, the handling of data, information, and their processed forms cannot be disregarded. From that point of view the definition of KM as the systematic and explicit management of knowledge-related activities [12][13][14] can be easily shared. It can also be agreed that a KM strategy must pursue a direct connection between an organization's intellectual assets, both explicit and tacit, and positive company results.

The analysis is based on some well-accepted definitions such, as the Ackoff pyramid [17] and the associated transformation process [16] that can be schematized as:

- The raw material is data
- Understanding of relationships in data gives information.
- Understanding of patterns in information gives knowledge.
- Understanding principles in knowledge gives wisdom

It is also relevant to pay attention to the identification of the opposite terms: absence or false data, misinformation and non-knowledge [18]. Most failures in critical systems, even causing loss of human life, can be attributed to misinformation or non-knowledge. Fail tolerant system design must take into account the flow of data, information and knowledge and establish procedures to avoid failures.

The new information is transformed into knowledge by means of internal processes of association. As in a complex state machine, new knowledge depends on input (information) as much as on the previous knowledge. This transformation is executed by human minds, individually, or by means of some collaborative interchange of ideas and thinking [12]. The transformation of knowledge in wisdom is the realm of pure human intelligence. At the present time we have a started the systematization of the basic actions [12]:

- Collection of data, maintaining daily record of data related to task and jobs.
- Processing of data in order to obtain information, and make the information available.
- Individual and collective processing of information to generate tacit knowledge.
- Try to make tacit knowledge explicit by socialization

The process should be effective and simple. Internally, as a tool, we are using a collaborative intranet that includes task management software, document repository, version control, wikis and forums.

For company-university collaboration we are analyzing a process based on the systematic accumulation of data, information and pre-processed knowledge that can be conveyed from company to university. Professors at the university can complete the process to synthesize new knowledge by using generalization and conceptualization. The new knowledge is conveyed back to the company and, in some cases, others possible recipients, such as students, by means of courses, papers or reports.

An example can illustrate this process. In recent years there has been a rapid transition in standards related to communication between CPU and peripherals in SBCs. A migration from parallel buses such as ISA or IDE towards high speed serial buses such as PCI-Express, SATA, or USB has taken place. A company can obtain initial knowledge of these new technologies by processing information from manufacturers and standardization bodies, and can also gain some experience in specific applications, involving both hardware and software design. Involvement of academia would undoubtedly be beneficial in this process. A university department can approach the study of high-speed serial buses from a broader perspective, and can even assign the subject in end-of-term projects or thesis. The work in progress is oriented towards the systematization of this kind of process, establishing systematic means of collaboration. More theoretical subjects such as application of formal methods in specification and validation of systems, model based engineering, reliability and fault tolerance, etc. can benefit of this industry-university interchange of ideas.

V. Conclusions and Future Work

The viability of an electronics system engineering company depends directly on the competitive quality and application of its knowledge assets. Realistic and effective management of those assets is an unavoidable strategic activity. University-industry collaboration is a mutually beneficial way of closing the knowledge of loop, conveying structured knowledge from academia to industry and experience in the opposite way, from the professional field to academia.

As a future work we are proposing a research project, devoted to analysis of techniques and processes applicable in competence and knowledge management. Other interested partners can join in the effort. The involvement of the Spanish University for Distance Education (UNED), with its ability to provide education and training to active professionals, would be very valuable.

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Scientific project management course introduction in doctoral studies in Riga Technical University

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Abstract - **Research activity is an integral part of the study process and it is to be noted that many of the research programmes are very important for the industry and economy of Latvia.**

Keywords - Scientific project management, doctoral study innovation, research and development

I. INTRODUCTION

Creative, effective and prestige – these are the three words that describe the scientific and research strategy of our University. Our goal is to stimulate and improve the development of all forms of human intelligence – from nature and social sciences to the high technologies.

Riga Technical University (RTU) is open to world-wide co-operation in scientific research and in education for sustainable development of knowledge based society. It provides general information on different fundamental and applied research projects carried out in our academic and research units. It also gives the names of our academic staff members as well as institutions involved in particular research areas. RTU plays critical role in technology development in Latvia. A lot of technological research, innovations and engineering activities in Latvia are completed by RTU graduates, RTU staff, but at the same time research organisations, that results in technological development in Latvia. RTU education structure allows pupils from schools to get all possible education in technological areas in the same place. Studies in RTU mostly is State financial supported, it is opportunity for everybody to make also scientific research and get PhD.

Doctoral studies play an important role in the new scientific staff education and attracting. The existing research facilities allow make scientific research, especially in scope of PhD. The main daily research work done by PhD students, mainly in technology development, results of these researches are often patented in Latvia. Nowadays RTU offers 23 doctoral study programs that provide doctor degree in engineering sciences, architecture, chemistry and economics. Every year hundreds of new students start their PhD's. The changes of student's amount in all programs are shown in figure 1.

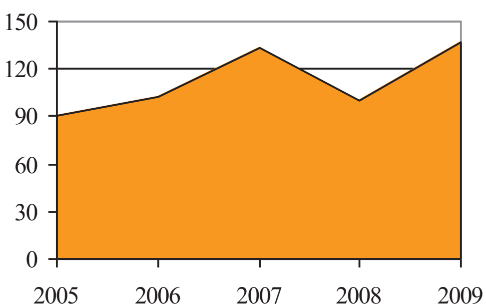

Fig.1. Doctoral students enrolment
(2005-2009 years)

II. DESCRIPTION OF EDUCATION STRUCTURE

There are about 500 doctoral students in RTU. The number of students in all programs is shown in figure 2 [3]. As a basic research force the doctoral students of RTU are employed in RTU as scientific assistants or researchers, according to qualification.

The RTU strategic priority is to archive 30% incomes of budget from scientific projects, involving in this way PhD students in regular research work, is important for RTU sustainable development.

The year 2008 budget of RTU was 62 Mil. EUR, but incomes from other scientific projects was just 2%. This means that the efficiency of usage scientific personal and equipment has potential to growth up in nearest future. The increasing of financial efficiency in RTU needs application of special methods, dissemination of scientific projects results and attracting new researchers is critical priority for RTU as a scientific institution. The main financial targets increased incoming finances from scientific research by 28 % next 5 years. According new scientific research it is important to have an infrastructure and, of course researchers.

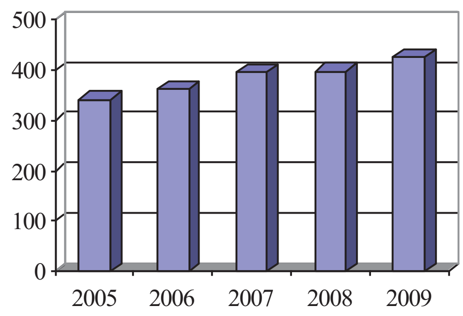

Fig.2. The dynamics of Doctoral students in RTU (2005-2009 years)

During two last years in RTU the common project control instruments and procedures were introduced. In figure 3 the fragment of formal project control tool is shown. In administrative structure of RTU also the special strategic department was introduced, with main responsibility to have formal control project documentation and other formalities, to keep in touch all formal project management cycle. However this control instrument and all departments could only control existing activities, but do not attract new scientific force to reach the target amount of projects. These procedures are not suitable to check scientific quality of project deliverables.

Fig. 3. The fragment of project control e –tool

To control of project deliverables scientific quality is project manager responsibility, and control procedures are different almost in each case, this issue is discussed in contract signature time.

To attract new researchers in scientific project development the such issue like free choice subject for PhD course students was introduced. The other issue is publication of project results in university newspaper "Jaunais inzenieris".

The main scientific cooperation in RTU is ongoing cooperation with industry partners from Latvia. That's way special RTU support programme was introduced. The amount of application on annual support for research in RTU this year was 34 projects, this amount shows active cooperation amount between RTU scientists and other companies. To attract young people in scientific research the special criteria as involving master students and doctoral students was introduced. To increase this active cooperation the attraction of new scientist is important, and in fact last few years main human resources in research are doctoral students.

The main measure of effectiveness of scientific research is amount of patents and trademarks. The patent and trade mark application amount are shown at figure 4.

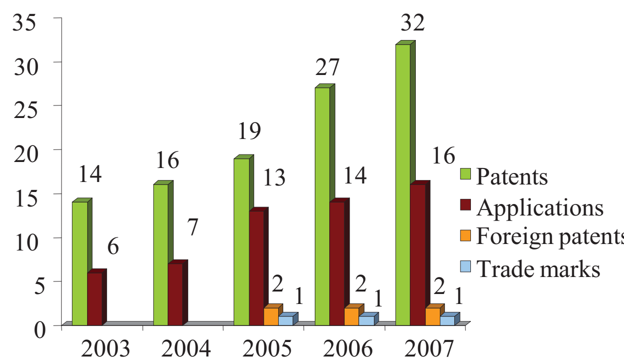

Fig. 4. The dynamics of patent application, foreign patents and trade marks

Most of the experimental works in laboratories were made by doctoral students.

III. Scientific Project Management Course Introduction

The doctoral students mainly become main researchers in RTU, so it is important to educate doctoral students, in time of doctoral studies and involve them into financially successful research.

There are doctoral programs, in which study subjects are divided into three blocks of basic subjects: compulsory subjects, subjects of obligatory choice and free choice. Within the time of three years for full time studies the subjects of free choice are considerably developed: „Management of scientific projects", „Intellectual Property Protection" and „Planning of experiments", pedagogy and other subjects are also accessible for the students of all RTU programs and from other Universities. During the study time the main is allocated for research and writing thesis. Every year the centralized assessment of doctoral student progress in research and studies is realised. The head of RTU Doctoral study department or deputy head of RTU Doctoral study department are present at these doctoral students progress meetings, so if the control of progress of research of the studies is centralised.

The development of doctoral studies in RTU deals with three main problems: financing, development of good relationship with industry, national and international partners. The course “Scientific project management“ was introduced in 2007, and still this course structure is under development. In 2006 the lecture note was written by professor I. Rankis and senior researcher N. Kunicina, so theoretical part of the course is written, but there are many practical and methodological issues to apply knowledge of project management into real scientific project preparation.

Each scientific investigation made by doctoral student is controlled by doctoral department of Riga Technical University, and scientific stuff in the Faculty or Institute. The course “Scientific project management“ helps doctoral students to structure their research, and to imagine all the process from the beginning of the research to commercialized result. Before this course it was not clear for students how to achieve market with their research results, because there was no structured information about scientific project management in Riga Technical University.

The main student’s response was that the information about project management and scientific product commercialization makes research more attractive and motivates doctoral students not only to get scientific, but also commercial applicable result after doctoral studies.

The product life cycle could be considered within two main parts: project and product management (see figure 5). The project stage requires financial investments and could be realised by scientific institution. Scientific project development technology could be separated in such project management stages: idea evaluation, research stage, conception stage, and realization and introduction stages. In introduction stage scientific institution should work together with a market company, which has bought product licence, or in other way has rights to commercialised product.

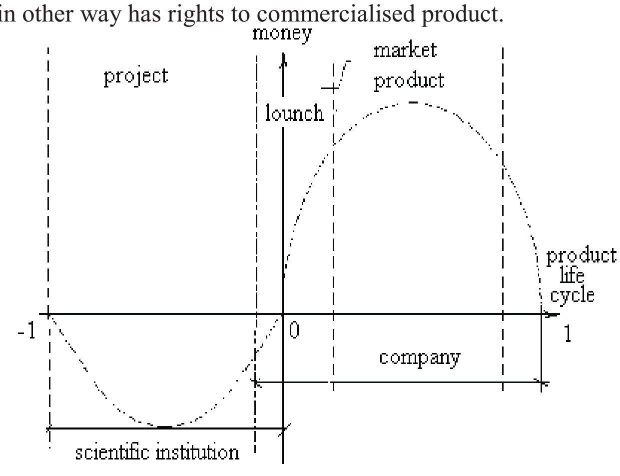

Fig. 5. Successful innovation commercialization cycle

Figure 5. presents a development cycle of a successful scientific investigation from the very beginning of the project till the final commercial application of the product. This diagram is used in “Scientific project management course” for schematic visualisation among product development and life time on market among time and finances.

Product management is divided in four stages: market introduction stage, growth stage, mature stage, saturation and decline stage. Market product management should be made by market company, and in case, if in product in mature stage will need some innovation, the scientific institution can made technical innovation, which could prolong product time in market.

Innovation is a very wide term that includes investigational, financial, market organization as well as a lot of other measures. Innovation development process is presented in figure 6 [2].

Innovations are connected with new technologies and implementation of the products with the help of scientific methods, i.e. scientific projects and their management. The scientific projects that are connected with new technologies and products implementation are considered to be applied by the researches.

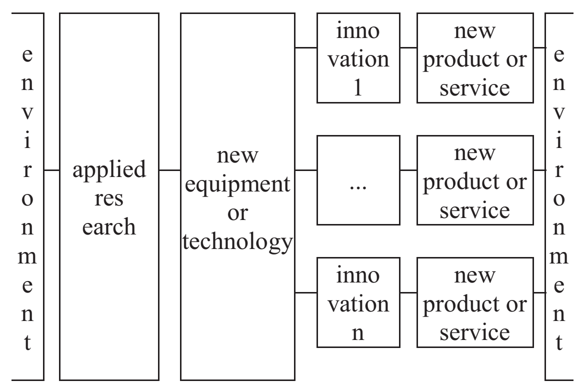

Fig. 6. Innovation development process

The innovative idea commercialization process is difficult for doctoral students. There are stereotypes and non structured knowledge that they have at the beginning of course. At the end of course they become skilled young researchers with structured knowledge about ways and possibilities to realize commercialisation of their research results [1].

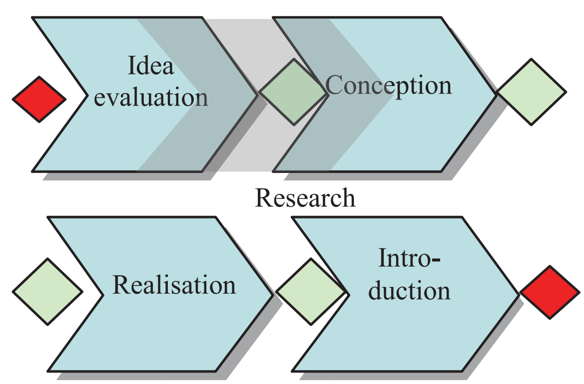

Fig. 7. Project realisation stages - development process and decision-making points

Project management is divided in four stages: idea evaluation, conception, realisation, introduction, and one additional research stage, which is actual for scientific research projects (figure 7).

Idea

Evaluation - Context

- Takes place when the idea has been defined and its strategic fit has been evaluated. Product development project begins

Objectives

- Product development activities aligned with strategic goals
- Ensure that core offering and customer needs and earning logic are defined, there are a basic understanding of market potential & competitive situation
- Ensure that technical feasibility has been reviewed
- The goals, milestones and desired outcome of the product development activities

Research

Context

- Takes place between idea evaluation or concept phases.

Objectives

- Development technology, product or methodology, to fulfil clients' requirements in a new way.

Concept development & evaluation

Context

- Takes place when the concept has been defined and evaluated against standardised concept description and evaluation template
- Implementation begins from this decision point

Objectives

- Ensure that value proposition is defined and core offering is tested by customer survey
- Ensure that the project has a business case and the solution is technically and legally feasible
- Ensure that implementation phase has relevant project plan
- In context of research projects in concept phase is important to ensure intelligent property of authors – make patent application, publishing scientific results, taking part in scientific conferences.

Offer development and launch planning (realization)

Context

- Takes place when the new product is ready to launch
- The market launch of the product is after this decision making point

Objectives

- Ensure that value proposition and business case are valid
- Ensure that the product is technically ready for launch
- Ensure that there are no open regulatory or legal issues
- Ensure that there is a relevant product launch plan

Introduction (Launch)

Context

- Takes place after launch has been carried out and evaluated to launch plan and business case

Objectives

- Ensure that market launch is evaluated and needed modifications are done
- Ensure that ongoing monitoring of product is planned and implemented
- Ensure that the product development project is evaluated

The knowledge structuring for doctoral students is one of three critical components to start scientific project, based on scientific research in doctoral studies. The other components is scientific research, with possibility to gate such final product, with ability to sell it on real market, mainly it should be new device, material or computerised program. The research results should not be too theoretical. The last component is ability of young scientist to work in risk condition.

IV. Finansial support

The supports of daily activities of doctoral students are grateful role for European Structural founds projects.

Since 31 of July 2009 doctoral study support project "Support of RTU doctoral study" Nr.2009/0144/1DP/1.1.2.1.2/09/IPIA/VIAA/005 has being realized. The European Union directly supports it in the frames of European social found financed projects. This is aim stupendous for doctoral students. In working programme annex 1.1.2.1.2. sub activity "Support for doctoral study programme". The activity in this project was started by organising competitions for doctoral students, and persons, who develop doctoral thesis (there is a special support for graduated students, who completes doctoral course, and who are going to defend doctoral thesis). Project realization duration is 76 month till September of 2015.

Aim of project is to increase of PhD defends amount, which will create and introduce in production new products, with high additional value, technological innovations. Doctoral research mainly is a base of new products development with high additional value. In this project frame approximately 300 persons will receive support. For scholars that is also a support of their scientific conference attendance and for supervisors.

During four years more than 360 RTU doctoral students and young doctors obtained grant and financial support for the purchasing of materials, visiting conferences, seminars, exchanging experience etc. Using also doctoral support financial resources doctoral students have a great possibility to cover doctoral and research activities and involve them themselves in scientific cooperation projects.

The Scientific project management course introduction in doctoral studies in Riga Technical University gives doctoral students structured knowledge in scientific project, in possibilities to apply projects at international level.

In natural figures, if the budget of RTU is 62 mil. Euro, the incomes from scientific projects should be 18 mil. euro per year. It seems, that target financing income from one researcher is 50 000 euro, or 550 000 euro per one scientific institute per year.

The main ways to have such financially successful researches are to evaluate scientific institution ability and skills of each researcher and show them possibility to achieve financial results in scientific teams.

Doctoral student's course scientific project management course is divided in two parts theoretical part and applied. Theoretical part allows to structured basic knowledge's about scientific project management, but practical application allows to student write formal application for scientific project tender.

The practical part for students is free choice topic. The experience since 2007 year is positive, but slow. The first students in the course as final paper presented their scientific research and novelty of scientific research, formalised in special way. The scientific projects scope, aim and work packages were formalised mainly in those projects. Next year the students have had prepared proposal for RTU scientific research projects, it was scientific project description with budget calculation, but this project total budget was not bigger then 20 000 euro. This year students prepare scientific project proposals in all three levels; there were students, which prepare projects with total budget more then 300 000 euro.

The introduction of course "Scientific project management" was successful, there was enough structured study material, hand book and competent teaching stuff. The results of implementation of this study course is not enough financially successful, it means, that knowledge's is just one of three components and it is not enough to start new projects. The motivation and ongoing support is important for starting new projects.

The other components is scientific research, was ability to sell final product on real market and the last component - ability of young scientist to work in risk condition.

The ability to develop and sell research final product on real market is mainly competence of scientific adviser head of structural unit - scientific institution. In particular in frame of European social found financed project „Development of doctor program and its quality in Riga Technical University", agreement Nr.2005/0132/VPD1/ESF/PIAA/04/APK/3.2.3.2/0050/0007 was introduced also other two important free choice study subjects „Intellectual Property Protection" and „Planning of experiments", this studies subjects helps students to formalised and finished their research results and make the market ready results of their research. Also additional infrastructure features was made for doctorants during this project. During the project „Development of doctor program and its quality in Riga Technical University" three teaching aids for the free choice subjects were developed, synopses of lectures were prepared, the thesis subjects has been developed with the aim to give an opportunity for young scientists to start first research projects within the doctor course, and to obtain scientific contacts and possibilities, consolidate RTU as a scientific institution enhancing from the research and investigations. The doctoral students who do not plan to continue the research can choose any subject of free choice from the register of subjects.

Using the seminar rooms (that were equipped during the project „Development of doctor program and its quality in Riga Technical University") provided also the use of the equipment within the project "Improvement of doctor studies effectiveness with the use of distance education" examining a lot of technical possibilities, purchased equipment: computers, notebooks, cameras, microphones, the opportunity to connect ten users into net was reached, that is useful for the doctor students individual tutorials and scientific work as well.

V. RESULTS OF THE PROJECTS AND FURTHER DEVELOPMENT

Third part to attracting doctoral student to take part in scientific research is knowledge in possibilities to apply projects at international level. The doctoral students during practical training have to know how to make qualitative project proposal and hove to apply for international founding projects. The main possibilities is to take part in COST, EUREKA (EUROSTARS), seventh framework programmes or other projects. The usage of some structural funds, which are managed in Latvia is also actual. The information about programme aims, structure, application procedure, samples of successful and not successful applications, this is the way how to motivate doctoral student to make his/her first application. Students realised, that they really could take a part in such projects, even that they haven't knowledge's about this projects and financing possibilities before they took part in this course.

The situation in Latvia, when research capability of small country is limited the cooperation with other international partners is critical to increase efficiency and financial incomes from research activities in RTU. The partner searching sometimes is not so simple, and the existing relation of scientific advisers is not enough for preparation of successful proposal at international level. In this time the Erasmus exchange program, European Cooperation in Science and Technology (COST) actions or any other direct cooperation programs are critical. The is possibility to find partners in conferences or from scientific societies, but this ways are not so efficient, as direct cooperation during research in common projects.

The experience in network of excellence was also positive just few years ago. The research activities of Institute of Electrical Engineering and Industrial Electronics of Riga Technical University L. Ribickis, A. Levchenkovs, N. Kunicina, Y. Chaiko, A. Ziravecka, V. Brazhis who took part in European rail research Network of excellence (NoE) FP-6 PLT – 506513 was created proposals in such topics: Operation and System Performance; Rolling Stock; Product Qualification Methods; Safety and Security; Environment and Energy Efficiency. Project proposal „SAFCORS: Safe and Cross-operable Rolling Stock" with 20 participants from 12 European countries for FP7 2nd call Area: Sustainable Surface Transport FP7-SST-2008-RTD-1 was appled.

The EUREKA project development now is very actual, because the is ongoing European Regional found project proposal frame "Business and innovations" 2.1.1.2.activity

"Support for the international co-operation of the projects in science and technologies, this financial resource allows to reimburse project proposal preparation expenses and it is chance for new researchers to get founding for future work in RTU as researchers. Unfortunately now work in EUREKA projects is not frequent, because of shortness of financial resources in Latvian budget, for example cooperation in EUREKA project Hybrid Modular Home Media Equipment was not efficient, because project team have to move activities, waiting till new year for financing and all this troubles negatively influence project realisation.

The partners search and project preparation for seventh framework projects are efficient just in particular cases. There is national contact point, which is responsible to support project preparation. The RTU awarded young scientist of 2008 Dr.sc.ing. Kaspars Kalnins during scientific project management course is specially invited to have a practical seminar and help student's to prepare the seventh frame work project proposal in efficient way. The annual competition for the award young scientists was introduced in 2006 with the aim to enhance scientific research in RTU, to involve young scientists in research activities and to evaluate the results of the scientific research work of RTU scientists.

The motivation of doctoral students is organised in all levels directly and not directly, as an example internal RTU projects financing scheme and evaluation criteria. The criteria to apply for research financing includes such quantitative criteria as published monographs, students books, articles, presentation of research results in international scientific conferences. As well the ready to market of final product - patents.

The improvement of the doctoral study program and technical equipment at RTU is long term investment politics in economics' sustainability. The sustainable development depends also on the availability of equipment, which meets modern technological requirements. The main priority in the research staff training in RTU is development of doctoral studies in high-technology research-intensive fields. Many financial possibilities, which we have during the last years allows using of more modern scientific equipment for experiments.

There is a good practice during recent years - support innovation commercializing, based on State financing, CONNECT network, and university – enterprises collaboration agreements. The education by involving the doctoral students in the research is still under development, but in some divisions we could see, that it really works. The subjects that are interested for a lot of doctoral students are prepared in web based format, using new equipment, which was bought in last four years. Implementation of the doctoral studies base facilitates the use of website environment for training purposes and for communication among doctoral students and contacts with cooperation partners in other countries. Development of doctoral studies at RTU promotes the development of human resources and helps to improve the situation on the enterprises developing the ideas ready for commercialization.

VI. Conclusions

Doctor studies play an important role in the training of scientific staff for sustainable development of Latvian economics. The application of project based learning approach in doctoral studies is main instrument to reach acceptable level of industry in Latvia. The analysis of case study of IEEI, which is a leader in RTU in project-based learning application shows, that such strategy application could increase the financial resources of institution more than two times. Research projects in the field of power electronics and electrical engineering. The annual scientific report informs on the main branches of the research activities, contact information of the staff, scientific results and the present scientific infrastructure. Special attention is devoted to the Doctoral students who will provide the development of science in future as the basic workforce.

The course helps doctoral students to structure they research, and to imagine process from the beginning of the research to commercialization. The main response was that the course research more sustainable and motivates doctoral student's also commercial applicable result after doctor studies.

The main motive force of knowledge based economy is innovative activity, which promotes the use of the newest science and technology achievements. Innovative activities promote the participation of professionally qualified experts in commercial activities and increasing demand of research work in universities and research institutions. The final results of innovation are products which are able to make competition in world market and services with high added value. Result provides important increase rate of gross domestic product, more work places for qualified specialists, which can promote economical growth, social welfare and country up growth.

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Introduction to Electronics as a Minor Subject

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Abstract — **Technical knowledge should not be limited to computer scientists and engineers. Also people outside these professions should have a basic understanding of technical concepts, trends and challenges. This paper describes a module of electronics for technical journalists and shows that electronics can be successfully communicated finding a balance between simplification and accuracy.**

Keywords – electronics, technological literacy, life-long learning, educational methods

I. Introduction

Technology has a major impact on today's life. Electronic circuits help us through the day, starting in the alarm clock that wakes us in the morning and the radio that gives us the news during breakfast. And the electronics in a smoke detector guards us during the night.

Below the surface, the advancement of electronics has a significant impact on society and economy. Looking at society first, a number of current developments are consequences from new technology. This can be illustrated with the MP3 coding and the internet. These two technologies enable an easy sharing of music with programs like Napster. The music industry objected and copyright laws were changed in a number of countries. So, technological advancement led to a major change in legislation.

Figure 1. Camera for video surveilance

Another example are closed-circuit television (CCTV) systems for surveying public areas (Fig. 1). While already in use, the increasing computing power will lead to new applications like automatic detection of "suspicious" behaviour or tracking of persons through a city. Here society needs to discuss, whether those systems are a valuable help for the protection against crime and terrorism or a threat to the privacy of citizens.

Looking at the economic impact, electronics is a key technology that enables other products. A modern car is only competitive with an anti-lock braking system and electronic stability control. Car manufacturers without access to those systems will not be able to sell their products.

The same applies to other product categories. A washing machine in the higher market segment certainly has a more stable mechanical body and more powerful motor compared to a budget washing machine. Nevertheless, a customer paying the higher price for the advanced machine also expects a sophisticated appearance, e.g. a small display giving the remaining runtime. Such electronics costs little but are required to sell the expensive machine.

This impact of electronics on our lives and the economy however is contrasted by a lack of interest in society as a whole. People outside engineering and computer science are often unaware of the role modern electronics plays. This lack of communication and understanding between two important groups in society, the scientists and the literary intellectuals, has been described in the influential 1959 talk of C.P. Snow "The Two Cultures" [1].

There are a number of reasons why we, the engineers and computer scientists, should try to change this situation. If we want appreciation or remuneration for our work, we need people to understand what we do and where our work has an impact. Furthermore, visibility of our profession draws prospective students. And we also want to interact with society and discuss the risks and benefits of new technologies.

Such a basic understanding of engineering and science is termed technological literacy and has been proposed in [2], [3], [4]. Individual courses are described in [5], [6] and a comparison of different approaches teaching technological literacy is given in [7].

Many of the described courses cover the broad subject area of physics and technology. Other dwell on systematic procedures in engineering by programming exercises. The course described here specifically focuses on electronics, which is a subset of technology, but a significant subset.

The paper reflects teaching electronics as a minor subject and gives experience based on a course held for technical journalists. The same approach could be used for students studying economy, law or political science.

II. Educational Objectives

While for every course its objectives should be defined, this is especially important when teaching a broad topic in limited time. Also a balance must be found between simplification and accuracy. For the course of electronics as a minor the following educational objectives were defined.

The students shall,

- be able to explain basic terms and components in the field of electronics,
- know the main tasks in design and manufacturing of electronic circuits,
- be able to assess new information about trends in electronics.

However, it must be noted that it is no course objective that students shall be able to design electronic circuits themselves. This will not be their task in their aspired professions.

III. Teaching Approach

A. Target Group

The most important recipients to have a basic knowledge about electronics are decision makers, like managers and politicians, as well as knowledge multiplier like journalists. The approach described in this paper covers a module of electronics for technical journalists, held at the Bonn-Rhein-Sieg University of Applied Sciences. The course has been held for five years with about 60 students each year. A similar course can be used in other degree courses and is offered as continuous education.

The teaching approach has to consider a heterogeneous group of students, both in respect of previous knowledge and interest. Graduates and students of the described study courses are normally quite familiar with applications of electronics, such as computers, mobile devices and automotive electronics. However, they often do not realize the technology behind the product.

B. General Teaching Approach

Looking at the complete field of electronics, students could consider it too broad to be covered in just one module. The first task of the instructor is therefore to structure the contents in smaller topics [8], [9]. Each topic corresponds more or less to a teaching block of 90 minutes.

The individual topics serve several purposes. Besides structuring the complete course, they help motivating students, because for every teaching block they are told the relevance and impact of "today's topic". This is important, as the motivation of students for a minor subject can be limited.

Also each topic provides a new entry for students who have missed the last lecture or could not keep up. Consequently it is possible to give some more in-depth lecturing for each topic, as students who do not fully comprehend more advanced concepts have the chance of catching up with the begin of a new topic at the next lecture.

C. Structure of Topics

Teaching time for the module are six lectures and six seminars, each having 90 minutes. The seminar also contains small lab exercises.

The complete subject has been structured into the following six topics, each approximately taking 90 minutes lecture [8].

1) Introduction, Basics

This topic motivates the course by discussing the impact on society and economy similar to the argumentation in chapter I of this contribution. Then the basic components like resistors, capacitors, diodes, transistors as well as printed circuit boards are explained. Additional to an introduction to electric circuits some considerations for manufacturing and device selection, such as packages and tolerances are discussed.

If students did not have a previous physics course, also electric charge, voltage and current can be covered. In this case, this topic could be extended to two 90 minute blocks.

2) Analog and Digital Electronics

Signals and circuits of analog and digital electronics are contrasted in this topic. The sine wave as the fundamental analog signal and the concept of calculating with zeros and ones are presented. Basic circuits for rectification and amplification as well as logic gates and flip-flops are introduced.

3) Semiconductors

After having learned about the function of diodes and transistors, this topic looks "under the hood" and explains the p-n junction as the physical effect that is active in diodes and transistors. While this is rather abstract, the complete field of electronics is based on the p-n junction, so it needs to be covered.

Also solar cells are explained which receive high interest from students due to the economic and environmental importance of renewable energy.

4) Design and Manufacturing

People not working as engineers have limited conception about the different steps during a design project but need a certain level of understanding when discussing the development of new products. Tasks like specification, circuit concept, circuit entry and verification are explained. Furthermore, sourcing of components and manufacturing is covered. The topic also looks at the introduction of new products and questions why a product can be a success or fail.

Especially this section is an addition to courses described in literature [7] as it emphasizes the economic impact of technology.

5) Micro- and Nanoelectronics

With the knowledge of semiconductors (topic 3) and electronics design and manufacturing (topic 4) this topic explains integrated circuits, covering technology, design and manufacturing.

Semiconductor memories are also explained and receive good students' interest, as the advancements in this field are apparent, e.g. in the rising memory capacity of USB flash drives.

6) Automotive Electronics and Embedded Systems

These two subjects should not be missing in an electronics course, representing an important application and the integration of electronics in a machine. Again, based on the previously discussed general knowledge of designing electronics some special considerations for embedded systems are explained.

D. Repetition of Important Concepts

Structuring the complete course into topics also allows reiterating basic concepts of electronics. Thus, students get a repeated chance for understanding.

For example, the transistor is discussed in topics 1, 2, 3 and 5. In the "introduction" (1) the basic function of the transistor as a switch and amplifier is explained. In "analog circuits" (2) a simple amplifier is presented. The topic "semiconductors" (3) explains the physics of a transistor and "microelectronics" (5) covers the integration of millions of transistors on a single device. Each time the transistor is discussed, giving stronger students the chance to apply their knowledge and weaker students to ask questions and get another explanation.

IV. SIMPLIFICATION AND ACCURACY

As the target group only needs an overview about electronics and will not themselves design circuits, the lecturer has the right and the duty to simplify the presented information. However, a balance has to be found so that the simplified information is still accurate.

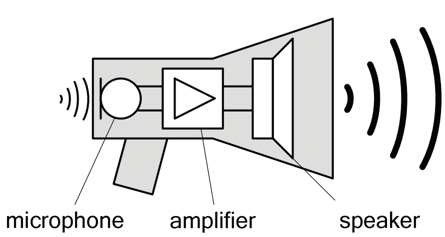

Figure 2. Megaphone as example for an amplifier

A. Transistor as Amplifier and Switch

How such a balance between simplification and accuracy has been established shall be discussed for presenting the function of a transistor. First, the need for an amplifier is illustrated with a megaphone (Fig. 2). The weak input signal shall come from the microphone and the sound is given to a speaker.

Then Fig. 3 shows the simplified function of an amplifier with a transistor. Controlled by the weak input signal the transistor opens the path from the power supply through the speaker. For an electrical engineer, the circuit might seem trivial, but it helps students grasping the concept of an amplifier. By discussing the circuit it becomes clear, that the transistor does not provide energy to the speaker but switches the flow of energy from the power supply through the speaker. Nevertheless, it is explained that a real amplifier, e.g. of a megaphone, has several amplifier stages and some more components like resistors and capacitors.

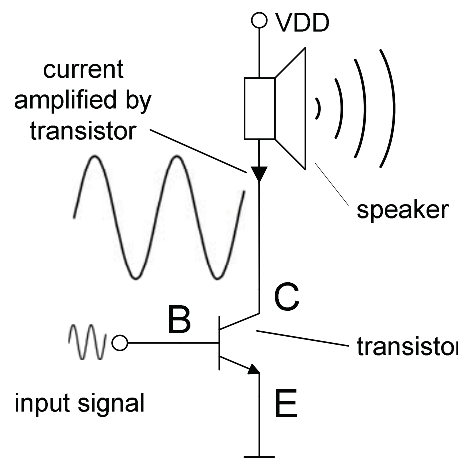

Figure 3. Transistor as an amplifier

Based on the simplified amplifier a real circuit is presented later in the seminar. It is a light sensor where a photoresistor senses brightness and the transistor switches an LED (light-emitting diode) on or off (Fig. 4). It is similar to a street lantern that automatically switches on during darkness. Compared to a real lantern again this circuit is simplified but it is a working circuit.

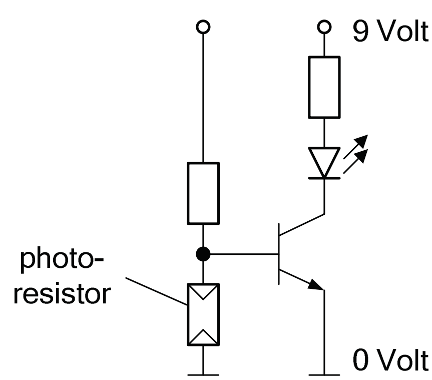

Figure 4. Street lantern with light sensor

During the seminar, the function of the light sensor is explained by discussing the two cases of brightness and darkness. In brightness, the photoresistor pulls the base of the transistor to ground and closes the transistor. In darkness the left resistor pulls the base of the transistor to 9 Volt and opens the transistor, the LED lights.

This explanation is simple enough for non-engineering students to comprehend. The circuit is also soldered on a printed circuit board in a hands-on lab during the seminar. This activity is motivating and gives the students the possibility to personally interact with electronics.

B. *Digital Circuit*

Another small example is used to illustrate the principal function of a digital circuit. A small dice shall be implemented that draws between four possible outcomes.

While a button T is pressed, the circuit switches between four states name A, B, C, D (Fig. 5). These states correspond to the four possible results of the dice. Switching is so fast, that a person pressing the button generates a random state upon release.

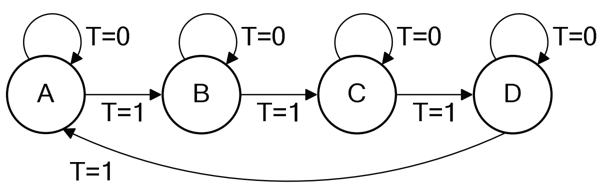

Figure 5. State diagram for simple dice

The circuit is implemented with two flip-flops storing the current state, some gates calculating the next state from the current state and some further gates calculating four outputs A, B, C, D that light LEDs giving the result of the dice (Fig. 6).

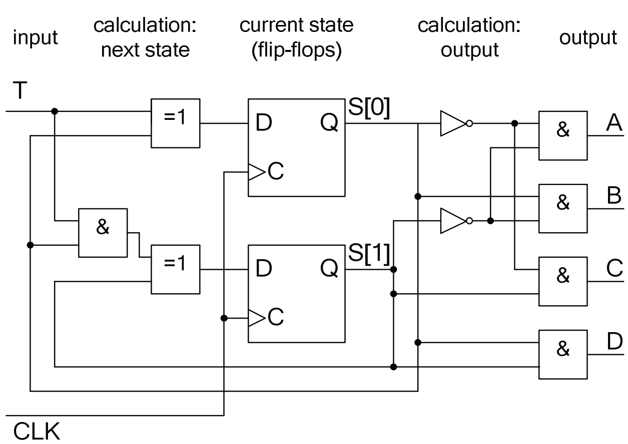

Figure 6. Circuit diagram of simple dice

The circuit is discussed with the students during the seminar and switching from one state to another state is calculated with paper and pen. A real hardware model of the dice has been constructed in a student's project. It shows the digital circuit at work and allows playing with the dice. As an addition a web based simulator is used to further demonstrate the circuit's behaviour [10], [11].

Again it must be noted that the digital circuit is working, but for a real application probably a small microcontroller would be used.

V. APPLICATION EXAMPLES

A. *USB Flash Drive*

Relating electronics to prior knowledge about technical systems is important to involve students in the module content. Also it underlines how the course is linked to topics outside the classroom. For this purpose application examples are used.

As an application example a USB flash drive is used to illustrate design and manufacturing of electronics. It is well suited due to several properties:

- As an everyday item it is well known to students.
- It only contains two integrated circuits with clearly defined tasks plus some small components.
- The product category undergoes rapid technological developments, especially with rising memory capacities.

B. *Specification and Circuit Concept of USB Flash Drive*

Different types of USB flash drives are known to students. They come as a simple mass storage or as an MP3-player with the option to store data. The design can be simple or fashionable. Optional features are a switch for write protection or data encryption.

All these options give the possibility to discuss the economic impact of the product specification with students. Which features are expected by customers? What is the cost impact? At which end of the market will the product be placed?

Based on the specification the circuit concept can be discussed. The block diagram of a USB flash drive (Fig. 7) is fairly easy to understand. A controller communicates via USB with the PC and stores information in a flash memory. Some LEDs are used as a status display.

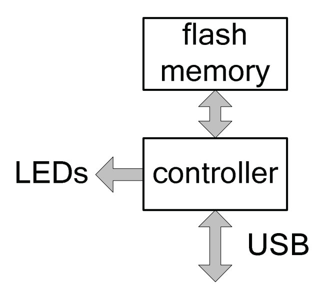

Figure 7. Block diagram of USB flash drive

With the block diagram further considerations for product design can be discussed. Often several controller can be used, some already available, others announced. Which shall be chosen? Should a small display be used instead of simple LEDs? These question will not be answered in the course, but illustrate the decisions engineers are faced during product design.

C. Design and Implementation of USB Flash Drive

Having discussed the block diagram the further steps in circuit design can be presented. Again, the students shall not learn how to perform these design steps but should be aware of the engineering tasks.

Implementation details from a commercial USB flash drive are available in a reference design [12]. This design is used to show students a complete set of engineering and manufacturing data including schematic, layout of the printed-circuit board (Fig. 8) and bill of material. A product photo (Fig. 9) shows the complete product.

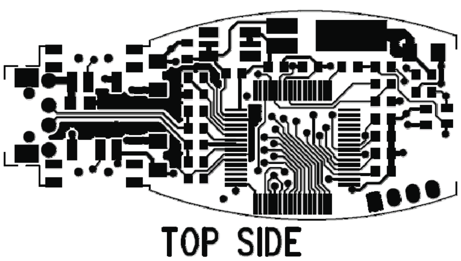

Figure 8. Printed-circuit board layout of USB flash drive [12]

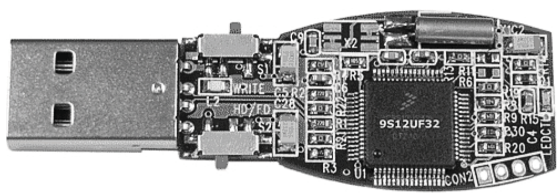

Figure 9. Product photo of USB flash drive [12]

Finally, also start-up of a prototype design is explained using the USB flash drive. In a first step an engineer will address the controller and try to read a device number and switch on/off the LEDs. Only if this works, the flash memory will be put into operation. Students can discuss to what extent parallel work of several engineers is possible and whether it makes sense trying to start-up the memory when the correct function of the controller has not yet been achieved.

D. Role of Application Examples

As discussed in chapter IV simplified examples are used for basic concepts, like transistor functionality or principle function of digital circuits. The application examples use a real design to relate the course to industrial products.

Other application examples use a stopwatch to illustrate programming of an embedded microcontroller [13] and the driver's door of a car to explain use and function of automotive bus systems.

VI. Observations and Evaluation

The experience of five years teaching electronics as a minor subject shall be given as personal impressions during teaching and discussing with students as well as a formal evaluation using a questionnaire.

A. Experience during lectures and seminar

During the course students showed significant differences in their abilities and motivation. Some students are already familiar with electronics, while others are very reluctant to engage with the subject.

This heterogeneity has been anticipated and led to structuring the course into different topics. For the weaker students it has shown to be helpful repeating important concepts several times. Students with previous knowledge were eager to discuss advanced problems.

B. Students' motivation and "weaker students"

Some more thoughts shall be given here about students' motivation and working with weaker students. Of course, every instructor wishes for students with high motivation who follow every word that is said and take the initiative to further dwell into the subject.

However, students' interest in minor subjects is often limited as they focus on the main subject of their studies. Also, they do not invest much time to compensate missing previous knowledge. While this is regrettable from the instructors viewpoint, it is an understandable approach from the students side.

Nevertheless, the experience of teaching an interdisciplinary course as a minor has been and still is very positive. Students with little previous knowledge might not reach a very high level of knowledge but often show a very steep learning curve and reach the educational objectives.

Also they might come up with interesting ideas for applications. For example, during discussing the electronic dice, a student asked whether the dice could be extended to give 20 different values. Such twenty-sided dices are used in role-playing games. So, while the student learned about electronics, the lecturer learned about role-playing games.

C. Formal Evaluation

In addition to discussions during the lab, a formal evaluation has been undertaken, to investigate to what degree students accept complex topics. In one degree program students also attend a hands-on lab and after the written test at the end of the term they were asked to judge three different lab exercises.

- A: "current–voltage characteristic" – This is a typical engineering exercise where the students measure the characteristics of resistors and diodes.
- B: "light sensor" – A very interesting exercise, where students solder a small circuit on a board (as discussed in chapter IV-A and with Fig. 4).

- C: “embedded system” – Here the students should modify C-code to program a stopwatch [13].

For the three exercises students have given marks in two categories. They should indicate whether the exercise helped for understanding the lecture contents and whether they could transfer the knowledge to real life. The value 1 means “excellent” and 5 is “poor”. Evaluating three exercises allows a better assessment of the embedded systems lab.

The results of the evaluation are shown in Fig. 10. A total of 56 students responded. As expected the interesting and entertaining experiment “light sensor” (B) gets a better evaluation than the a bit tedious “current–voltage characteristic” (A). These values are used as reference.

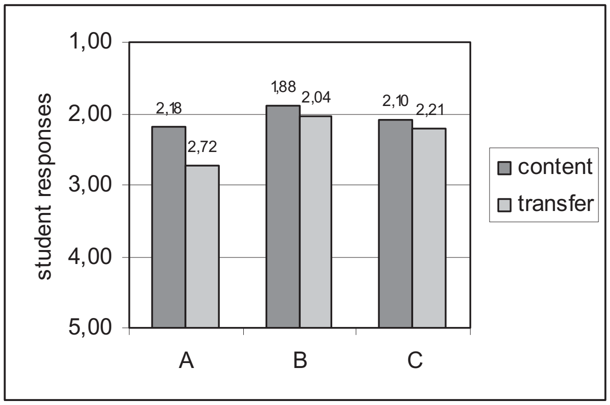

Figure 10. Evaluation of three lab exercises

The relevant result is the evaluation of the “embedded system” exercise (C). Here students without previous programming experience were a bit overchallenged. However the evaluation showed, that they accept small frustrations and give this exercise good ratings.

This becomes especially apparent looking at the different responses for content and transfer to real life. Exercise A (“current–voltage characteristic”) is accepted as giving knowledge for the exam. However, the students do not see much value of this information for their professional life. In contrast, for the “embedded system” exercise (C) students realize that they can transfer the knowledge they gained outside the classroom.

VII. Conclusion

The basic concepts of electronics have been successfully taught as a minor subject to non-engineering students. Key to the lecture is a strong focus on the educational objectives, accepting that students will not design electronics themselves. They rather have to comprehend and assess information about electronics and be able to professionally interact with engineers and computer scientists.

In addition to other technological literacy courses, the economic impact of electronics is emphasized, linking the course content to other subjects. Also this provides the application for the students, as their assessment of technology will be based on economic merit.

Organizing the course into clearly differentiated topics allowed coping with the heterogeneity of students. To students with previous knowledge, more advanced information could be given, while enabling students with little previous knowledge can catch up at the beginning of a new topic. Discussions with the students and the evaluation show that students engaged in the topic and believe they can transfer knowledge from class to real life.

Acknowledgements

The semiconductor manufacturer Freescale allowed the used of extensive information from its USB Thumb Drive Reference Design in the lecture and the textbook which is gratefully acknowledged.

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Role of Faculty in Promoting Lifelong Learning: Characterizing Classroom Environments

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Abstract— **Calls for educational reform emphasize the need for student-centered learning approaches that foster lifelong learning. To be a lifelong learner includes characteristics consistent with those of self-directed learners, such as being curious, motivated, reflective, analytical, persistent, flexible, and independent. Educational research has shown that the building of these aptitudes involves a complex interplay among nearly every aspect of human development. Instructor support of students' self-directed learning (SDL) development relies on understanding and balancing these factors in the classroom. Engineering educators play a critical role in influencing outcomes related to SDL through their design of courses that support students' transitions from controlled to autonomous learning behaviors. This study will examine a variety of engineering courses and pedagogical approaches. Each will be characterized using instructor course information, videotaped classroom observations of instructor-student and student-student interactions, student and instructor responses to surveys, and focus groups. Finally, the students' capacity for SDL will be measured using the Motivated Strategies for Learning Questionnaire. This approach should provide for rich, contextualized descriptions of what instructors and learners do, how instructors and students relate to each other, and how students view their classrooms. This work-in-progress paper will describe our initial work in this multiyear study.**

Keywords-Lifelong learning, Autonomy support, Self-directed learning

I. INTRODUCTION

Calls for educational reform emphasize the need for student-centered learning approaches that aid development of broader skills and attitudes such as a capacity for lifelong learning [1,2,3,4,5]. Engineering educators as well as ABET recognize that students' development of such a capacity is vital for their success in today's global and rapidly changing engineering environment [4,5,6]. However, the current emphasis – particularly in the engineering education community – seems to be on assessing students' lifelong learning abilities, rather than on understanding the relationship between instructor practices and lifelong learning outcomes. To be a lifelong learner includes characteristics consistent with those of self-directed learners, such as being curious, motivated, reflective, analytical, persistent, flexible, and independent.

Designing learning environments and activities that engage students in self-directed learning (SDL) and foster the growth of autonomous individuals, however, is not a simple task. With its introduction of program outcome (i) "a recognition of the need for, and an ability to engage in lifelong learning," as a requirement for all engineering graduates, ABET essentially challenged engineering educators to determine how we may best engage students in SDL (and eventually lifelong learning). To effectively promote SDL, faculty need to be skillful in facilitating pedagogies that engage students in self-direction, be sensitive to and understand student attitudes and behaviors in SDL settings, and be aware of the roles that classroom environments can play in aiding students' SDL development.

The limited existing studies show no significant gains in undergraduate engineering students' capacity for SDL via traditional instruction [7,8]. However, nontraditional instructional practices such as problem-based learning are more explicitly designed to develop student attitudes and skills relevant to SDL, and there is some literature support to suggest that these approaches are more effective at developing self-directed learners [9]. There remains, however, little empirical data on those factors that promote SDL amongst undergraduate engineering students, especially from carefully designed studies using validated instruments. This multiyear investigation seeks to fill that gap by conducting an observational study that examines a range of engineering environments, carefully characterizes instructor practices regarding support of student autonomy, and analyzes the relationship between classroom environments and proxies for lifelong learning such as SDL behaviors and attitudes.

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II. BACKGROUND

A. Defining Self-Directed Learning

One of the greatest challenges associated with SDL lies in its definition. Some engineering educators may consider it as a single skill that individuals either have or lack. In reality, the building of SDL aptitude involves a complex interplay among nearly every aspect of human development. Individuals become self-directing through mastery of a broad range of skills, attitudes, and knowledge [10-17]. The education literature includes extensive discussion of the competencies and attitudes of effective self-directed learners [18-21] and descriptions of the many factors that affect student growth in autonomous learning environments. These include cognitive and metacognitive factors [11,22] motivational factors [11,23], behavioral components [24,25] and contextual and social aspects of learning [22,26-30].

Motivational, cognitive, behavioral, and contextual factors are clearly interrelated, and the support of the development of students to become self-directed learners relies on a complex balancing of these factors in the classroom. For example, much is known about the relationship between student self-direction and motivation, and about the importance of fostering positive student attitudes and behaviors for engagement in SDL environments. Autonomy has been shown to increase students' intrinsic motivation, self-efficacy, and perceptions of task value [31-33], and use of cognitive and metacognitive strategies for learning and adaptive motivational strategies [34]. Black and Deci further demonstrated that autonomy-oriented students had higher perceived competence, higher interest and enjoyment, and lower anxiety and grade-focused goals [27]. Zimmerman emphasized that in addition to metacognitive skills, students need a sense of self-efficacy and personal agency for success in self-directed environments [35].

B. Role of Instructor in Self-Directed Learning

Although much of the burden of developing SDL competence falls on students, instructors also play a critical role in effectively promoting individual SDL development both through their instructional choices and their interactions with students. Autonomy support is one such area in which different practices may yield different outcomes. Black and Deci, in their investigation of undergraduate students in organic chemistry, revealed that students' perceived instructor support of autonomy related to improved perceptions of competence, interest and enjoyment, and ability to self-regulate [27]. Opportunities for individual choice, control, authority, and responsibility appear to be important elements in both the academic achievement and the psychological development of students.

Table I, developed by Stefanou et al. [28], provides a framework for characterizing different types of autonomy support that may help develop students' self-directed learning, along with examples of specific instructor strategies. In this framework, Organizational Autonomy Support includes student choices that are primarily related to contextual factors (e.g., selection of team members) and behavioral factors (e.g., managing due dates). Procedural Autonomy Support includes choices related to students' intrinsic motivations (e.g., discussing their wants and displaying individual work), and some opportunities that connect motivational and cognitive strategies (e.g., selection of resources). The Cognitive Autonomy Support describes choices that relate directly to students' mental processes during learning (e.g., self-reflection on errors, consideration of multiple solutions and strategies).

TABLE I. STRATEGIES ASSOCIATED WITH THE DIFFERENT FEATURES OF AUTONOMY SUPPORT

Organizational Autonomy Support	Procedural Autonomy Support	Cognitive Autonomy Support
Students are given opportunities to: • Choose group members • Choose evaluation procedure • Take responsibility for due dates • Help create class policies	Students are given opportunities to: • Choose how competence is demonstrated • Display individual work • Discuss their wants • Choose resources to use	Students are given opportunities to: • Discuss multiple approaches • Find multiple solutions • Justify solutions • Be independent problem solvers • Reevaluate errors • Debate ideas freely • Have less teacher talk time; more teacher listening

Unfortunately, there is little solid empirical data that shows how instructor choices promote or hinder SDL development in undergraduate engineering students. Of the many factors that contribute to the student response in autonomous learning environments, perhaps the least explored are the contextual or environmental factors. In 2000 Paul R. Pintrich noted that "there is a clear need for more descriptive, ethnographic, and observational research on how different features of the context can shape, facilitate, and constrain self-regulated learning [13]. Nearly a decade later, the need remains. Studies have shown that students' positive perceptions of their assigned tasks and instructors' autonomy support can lead to increases in intrinsic motivation, self-regulation, perceived competence, interest, engagement, and academic performance [34,36,37], but the connections between these student perceptions and the instructors' choices in course design and classroom environments remain unclear.

Clearly, there exists an opportunity for researchers to identify approaches, interventions, interactions, and contexts that promote the development of SDL skills in undergraduate students. In particular, there is a need to provide a deeper understanding of the relationship between the types of student autonomy support and the development of SDL competencies. Our study will aid instructors' understanding of how their classroom practices affect a range of student outcomes related to lifelong learning. We expect that variations in ways that instructors support student autonomy will influence students' development as self-directed learners. We aim to gain a clearer understanding of how aspects of course design and implementation relate to student responses and learning outcomes by exploring these questions:

1. In what ways do engineering instructors assist students to become self-directed learners? Are there instructor practices

and behaviors that lead to greater student involvement in and ownership of their own learning?

2. What are students' behavioral and affective responses to different ways autonomy is supported in undergraduate engineering settings?

3. What effect does a sense of autonomy have on students' perceptions of their own learning?

III. Methodology

A variety of different undergraduate engineering course environments will be examined as part of this study. The courses span nearly all academic levels, include both lecture and laboratory settings, and provide a range of pedagogical strategies that emphasize active, collaborative, problem-based learning, and project-based learning. This study focuses on active learning environments since these have provided the most promising results to date for developing students' capacity for self-directed learning.

Although all of the classroom settings may be characterized as "active," the different courses will present recognizable differences in the types and amounts of student choice and control, as well as differences in the classroom environment characterized in terms of student-student and student-faculty interactions in support of student autonomy. As such, these courses provide an opportunity to study the relationships between differences in autonomy support on the development of SDL-related competencies of motivation, student autonomy, and cognitive and metacognitive strategy use. We anticipate the different courses will provide wide variety in the type and level of organizational, procedural and cognitive student autonomy support. The rigorous characterization of the classroom environment with respect to student autonomy support is the first phase of the evaluation component of this project and is the focus of this paper.

A selection of class sessions for each of the instructors will be studied intensively through the lens of autonomy-supportive practices. To do this, syllabi and classroom artifacts in the form of classroom assignments will be collected, selected class sessions will be videotaped, and the instructors will complete a survey that measures personal epistemology. Students will be asked to complete a survey that measures the aspects of motivation, autonomy, and cognitive and metacognitive strategy use that are associated with SDL at the beginning of the semester and again at the end, and students will be videotaped along with their instructor during preselected class sessions. At the completion of the course, the instructors will be interviewed to discuss the choices they made in their course and students will be interviewed to discuss how those choices affected the variables of interest in this study.

IV. Work in Progress

We are in the first year of this three-year study, and are beginning the process of characterizing our various classroom environments. We will report on preliminary findings at the conference. Here we describe the various courses and characterization methods in this first year.

A. Descriptions of Courses

Heat and Mass Transfer is a required course for third year chemical engineering students. It adopts a problem-based learning structure in which students work in teams to solve a variety of open-ended, relevant engineering problems. Students are provided limited organizational autonomy support (they have some influence of team members and due dates) and more significant procedural autonomy support (they have significant influence on the selection of resources and regular opportunities to discuss their wants). In addition, the course incorporates very substantial cognitive autonomy support elements in that students are engaged in regular discussions of multiple approaches and solutions to problems with heavy course emphasis on justifying their solutions and exhibiting independent problem solving strategies.

Circuits is a sophomore-level course for electrical, industrial and mechanical engineering majors. Faculty-student interactions occur primarily during class lecture periods. In a typical class period, the professor prepares notes in PowerPoint which are projected using a TabletPC. The notes are intended to provide the outline and structure for the discussion of the topic, and there are many spaces where students are encouraged to write in their own notes, answers to questions or solutions to problems. Students are often asked questions to be sure that they are following, and they are called on in order going around the room to be sure that everyone is involved. In short, there is a reasonable amount of faculty-student interaction during these times but little student-student interaction during this time.

Most periods of the Circuits course also include at least one activity for which the problem statement is included in the notes along with whatever supporting information is necessary. Students are told to "turn to a helpful neighbor" and work out their solution. Students then work together on the problems while the professor walks around the room and checks in with groups, asks questions or answers questions. During this time, there is a fair amount of faculty-student interaction and student-student interactions within their groups. Finally, there are significant student-student interactions in cooperative-learning homework teams. Three to four students are assigned to each team at the beginning of the semester and each team meets weekly to work on the week's assignment. Team members rotate through various roles on the team and submit one solution set.

Failure Analysis and Prevention is a project-based, upper-level elective course for engineering students. Student development in the course is focused on professional-level competencies and application of self-directed learning skills. By organizing and carrying out self-directed failure investigations of real-world components and systems, and through analysis of published case studies students learn failure analysis by doing failure analysis. The projects emphasize the interdisciplinary nature of failure investigations, and they provide students with the opportunity to select team members and due dates (organizational autonomy), identify resources and express their own goals (procedural autonomy), and select learning strategies, manage class time, align learning with their own goals, and self-assess their project work as well as their development as a team member and lifelong learner (cognitive autonomy). Throughout the projects, the instructor serves as a consultant and a sounding board for students' experimental strategies and data analyses. Some of the class periods are devoted to open-ended discussions and debates of contextual factors that contribute to engineering decision-making. In the first half of the semester, the instructor provides weekly reading assignments and facilitates an in-class discussion of the readings. In the second half of the semester, student teams take responsibility for the selection of readings and facilitation of the in-class discussions.

The final course under study in the first year, Thermodynamics II, is a required course for mechanical engineering students. The course is taught in a lecture format with homework sets, quizzes, and midterm and final exam. It relies on the least amount of formal team work both in and out of class, and opts instead for peer teams formed *ad hoc* during class meetings. The instructor uses active-learning techniques during class, including the use of clickers and "turn-to-your-neighbor and discuss." Outside of class, students are highly encouraged to work in small groups to complete the assignments, but each student is expected to submit a homework, if he or she elects to do so. In addition to active-learning techniques, the instructor makes available partially completed notes, and incorporates some conceptual questions (using the clickers) to get away from focusing only on calculation-based examples. A typical class includes a brief lecture (less than 10 min) and quickly moves to problem solving. The instructor sets up the problem (describing it, providing known values, etc.) and breaks it into small 'chunks' or steps, which is then turned over to the students to solve individually. The students' understanding is then checked using the clickers. When there is some confusion as to the correct answer, students form impromptu two-person teams to discuss the question, and then are retested using the clickers. This procedure is repeated until the problem is completed, at which point a new problem or topic is begun.

B. Evaluation Methodology

A mixed-method approach will be used to examine how instructors support and facilitate student autonomy and other outcomes associated with SDL, such as motivation and cognitive and metacognitive strategy use. The evaluation plan includes:

- Characterizing the learning environment within the chosen engineering courses with respect to support of student autonomy and authority
- Using surveys to collect data on student outcomes relevant to lifelong learning in the diverse classroom environments
- Conducting focus groups with student to develop a deeper understanding of emergent themes in the student responses to instruction in the different course settings
- Conducting semi-structured, open-ended instructor interviews to develop a deeper understanding of the instructors' rationales for instructional decisions with respect to objectives associated with supporting student outcomes associated with lifelong learning

Each of these elements is described in more detail below, and a summary of the evaluation goals and assessment tools is shown in Table II.

1) Characterizing the Learning Environment

The classroom environment will be characterized according to the rubric developed by Stefanou et al. [28], which breaks student autonomy support into the three categories of organizational, procedural and cognitive autonomy support. This characterization of the classroom environments will use instructor course information (e.g., syllabi and assignment descriptions), videotaped classroom observations of instructor-student interactions, student surveys using the Learning Climate Questionnaire (LCQ) [39] and instructor surveys using the Epistemic Beliefs Inventory (EBI) [38]. In addition, student responses to the LCQ survey, focus groups and student dialogue from the videotaped class sessions will be used to gauge students' perceptions of the degree to which the learning environment supported their sense of autonomy. This approach should provide for the creation of rich, contextualized descriptions of what instructors and learners do, how instructors and students relate to each other, and how students view their classroom environments.

2) Assessment of SDL Outcomes

Students' capacity for SDL, defined in terms of motivation, autonomy, and cognitive and metacognitive strategy use will be measured at the start and end of the term using an available validated survey instrument (MSLQ) [40]. This instrument provides the opportunity to correlate differences in relevant outcomes with specific instructor practices and classroom environments. Multivariate analyses of variance will be used to evaluate the effects of time and the independent environmental variables on the multiple dependent variables such as student cognitive strategy use, self-efficacy, and motivation. Causal model or path analysis will be used to build a model that describes how different instructor approaches lead to different student psychological outcomes. This model development will include determination of the correlations between instructor approach and student outcomes, and between and among the dependent variables. Cronbach's α values will be calculated to determine reliability and temporal stability of the quantitative assessment data. Inter-rater reliability estimates will be calculated to determine the degree of rater agreement on the data coded for autonomy support.

Student focus groups and instructor interviews will be used to develop a deeper understanding of emergent themes in the student responses to varying levels of learning autonomy in the different course settings and instructional decision-making. The design of the formal interview protocol will be guided by the classroom observations and survey results, but possible areas of focus include students' and instructors' goal-setting and planning; student monitoring and self-evaluating of learning; instructors′ environmental structuring; self-view as an autonomous learner and instructor; affective responses to choice and control; internalization of learning goals; time and effort management; active help-seeking; and reflections on learning and behaviors.

TABLE II. OVERVIEW OF PROJECT GOALS AND ASSESSMENT TOOLS

Project Goal	Assessment data and Evaluation Tools
Characterize the classroom environment with respect to student autonomy support	• Course information (syllabi and assignments coded for task, procedural or cognitive autonomy support) • Classroom observations (videotaped and analyzed by coding for task, procedural or cognitive autonomy support) • Instructor surveys (Epistemic Beliefs Inventory [38] will be completed and correlations calculated between scores on this instrument and type of autonomy support practiced as determined on the basis of the coded data from videotapes and artifacts) • Student surveys (Learning Climate Questionnaire [39]) • Student statements from videotaped classroom sessions, coded for evidence of statements associated with autonomy beliefs • Instructor interviews recorded and analyzed for reflection on teaching practices that support autonomy • Student focus groups videotaped and analyzed for consistency with observations from videotaped class sessions
Assessment of SDL outcomes	
• Cognitive and metacognitive strategy use	• Student completion of Motivated Strategies for Learning Questionnaire (MSLQ) [40]
• Motivation	• Student completion of MSLQ
• Autonomy	• Student completion of MSLQ
• Behavioral regulatory strategy use	• Student completion of MSLQ

Analyses will involve transcription of all interview data and audio/video recordings; coding of interview transcriptions; and comparison of coded data to frameworks for SDL. Correlation analyses will illuminate the existence and strength of relationships between instruction and a range of outcomes tied to SDL. Based on the proposed assessment tools, we expect to identify correlations between the type and degree of instructor support of student autonomy, authority, and feelings of competence and students' motivation, self-efficacy, self-regulation, perceptions of the environment, and perceptions of lifelong learning competency development.

3) Summary of Evaluation Plan

The mixed qualitative and quantitative approach proposed in this study will enable examination of how the instructors' choices regarding support of student autonomy in courses may affect the classroom climate and ultimately students' development as self-directed learners. The results from the proposed investigation will be a valuable resource for all engineering educators who strive to help their students develop lifelong learning skills and ultimately enable them to be successful in their careers.

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Session 02F Area 4: Pedagogies

The development of professional mentoring for engineers undertaking a workbased learning Masters degree

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Cooperative work and continuous assessment in an Electronic Systems laboratory course in a Telecommunication Engineering degree

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Intelligent evaluation in educational context

Alimi, Adel; Besbes, Riadh; Moncef BenKhélifa, Mohamed; Gorce, Philippe
South University of Toulon (France); National School of Engineering in Sfax (Tunisia)

Meaningful learning checking of concepts related to equations and functions in Physics Chemistry according to the main theme gas laws.

Costa, Rodrigo Garrett; Ferreira, André Luis Andrejew; Zaro, Milton Antônio
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Professional Engineer Recognition

The development of professional mentoring for engineers undertaking a workbased learning Masters Degree

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Abstract — **this paper describes a method of recognising and assessing learning at Masters Level alongside the monitoring of engineering competence development in the work-place. For successful participants in the programme the outcomes lead to a Masters Degree and recognition as Chartered Engineers in the United Kingdom. It concentrates on the monitoring of professional development and competence assessment through the work of appointed Professional Supervisors.**

Topics: *Area 4: Active Learning, Area 4: Learning Models, Area 4: Pedagogies*
Keywords: *mentoring, workbased, competence, pedagogy, professional*

I. Introduction

In 2008 Kingston University, London initiated a new MSc Professional Engineering program undertaken through work-based learning, in collaboration with the UK engineering regulatory body, the Engineering Council, London.

This paper explains how and why this initiative to develop a new learning model has come about and how it has provided an innovative approach to the mentoring of developing engineers. In particular it concentrates on the theme of competence monitoring and how professional supervisors interact with the engineers who are participating.

The process of providing learning targets is summarized. These develop the necessary knowledge and understanding at Masters Level within individual learning contracts. Also, presented in more detail, is how the competences necessary for Chartered Engineers are monitored and assessed.

The underpinning theory of mentoring we are using is explained together with details of how industrial mentors are brought into the mentoring process alongside professional supervisors appointed by the university. Also explained is the pedagogy of problem-based active learning that we have developed within this program.

The current structure of the role and responsibilities of the professional supervisors is clearly spelt out and explained with details of their activities, training and reporting mechanisms.

The very positive feedback from both employers and students or participants [1] that has been forthcoming is evidenced through the participation of major UK-based and global engineering companies that are impressed by the motivation of their employees; the paper describes how an international support and mentoring strategy is being developed specifically to support participants globally.

Finally, an evaluation is made of the successes and challenges presented by this new program together with an explanation of how interested parties may become involved in it internationally.

II. Background

There is a shortage of registered Chartered Engineers in the UK, yet there are many engineers working successfully within many UK companies who are not registered. Some have the qualifications, experience and competence but have just not applied. However, an even greater number are able, have experience and are potentially very competent but do not possess the qualifications necessary to be registered. Attending a university to gain the necessary Masters degree is financially and socially quite difficult for them, involving, as it must, periods of absence from the work-place. A work-based learning Masters degree in engineering can solve this problem.

Kingston University, London has nearly 10 years experience of running Masters Programmes for professionals in many disciplines entailing the evaluation and assessment of work-based learning (WBL): the Masters by Learning Contract. In Engineering this has developed through the UK Government's Gateways to the professions Project in engineering[2], based at the Engineering Council, London into a nationwide Masters

[1] As the students are mature it is customary to refer to them as participants.
[2] http://www.engineeringgateways.co.uk

degree: the MSc Professional Engineering. Now, several universities[3] in the UK are running programmes based on the Kingston model: the model described in this paper.

The initial stage of the MSc or Entry Gateway consists of a Professional Development Audit in which there are three elements. For each of these, an in-depth analysis is required from the participant in the form of a printable electronic document:

- Evaluative Review (ER) or Reflective *Curriculum Vitae*
- Learning Contract (or Agreement) (LC)
- Competence Demonstration Action Plan (CDAP)

Once these three documents have been assessed as reaching the required standard by the university the participant's enrolment is confirmed and the documents are supplied to the participant's Professional Engineering Institution (PEI). Participants need to become members of the PEI before they can fully enrol on the MSc. The PEIs who initially signed up for the MSc are the:

- Institution of Engineering and Technology (IET)
- Institution of Mechanical Engineers (IMechE)
- Royal Aeronautical Society (RAeS)

Other PEIs are currently joining this group[4].

Each participant works towards seven learning targets (or goals) contained within the LC. The last of these is the Exit Gateway, a reflective summary, which includes a *viva voce* examination and if this is successful, the participant is awarded an MSc Professional Engineering.

The programme normally takes two to three years to complete, during which each participant is advised, monitored and assessed by an Academic Supervisor appointed by the university.

A requirement for registration by a PEI as a Chartered Engineer (CEng) is the attainment of competence as described in the Engineering Council's United Kingdom Standard for Professional Engineering Competence (UK-SPEC) [1]. In this Standard a range of competences is described in depth and these require underpinning knowledge at Masters Level. The MSc Professional Engineering provides this knowledge through WBL. However, the competences themselves require to be demonstrated in the work-place. A university appointed Professional Supervisor monitors and advises the participant and the employer on how the competences are being met and provides reports to the university. Although meeting the competences is not a requirement for the award of the MSc, the PEI is informed of progress and undertakes a Professional Review and Interview (PRI) once the participant has completed the MSc. Successful completion of the PRI results in professional registration as a CEng.

III. Learning Contract and Targets

Learning Targets (or goals) are set during the establishment of the Learning Contract. Each is based on the work the participant is expected to undertake during the programme. These are rated in Credits [2]. 180 M-level Credits are required in the UK for the award of a Masters Degree. 15 of these are awarded for the PDA at the Entry Gateway and 40 for a successful Reflective Summary and *viva voce* examination at the Exit Gateway. The remainder are set for any acceptable Masters level prior learning for which there is evidence and each of the other 5 Targets. These targets are generally set for 10 to 30 credits each and require a deliverable outcome which can be assessed. Examples of such deliverables are:

- Report on a project undertaken
- Technical or Management report
- Presentation to be delivered to a defined audience
- Major computer programme: documented, relevant, complex and demonstrable
- Paper for publication in a learned journal
- Research results and accompanying paper for publication
- Document on Social implications, Sustainability, Ethics or Environmental issues
- Effective and engaging talks or activities provided to school, college or university students

Once these are agreed between the participant and the Academic Supervisor with the acceptance of the PS, the LC is completed.

IV. Competence Monitoring by Professional Supervisors

The main role of the Professional Supervisor (PS) is to ensure that the competence requirements of UK-SPEC are met in as regular a way as possible. Each PS encourages the participant to assess and note the evidence for existing competence. Once the LC has been agreed, he can help the participant to make an assessment of expected competence development over the period of the programme, together with the necessary evidence. At this stage, the CDAP is completed and provided to the university by the participant.

The PS visits the participant on a needs basis and on average makes 4 or 5 visits per year to the work-place. Each visit is about 3 hours long. Starting with the CDAP as a base, the participant's activities and progress towards meeting the competences are his principle concern and he liaises with the employer's staff whenever necessary: the participant's line manager, company mentor and human resources personnel. He also keeps in close touch with the Academic Supervisor in

[3] Kingston University London, the University of Hertfordshire, Northumbria University and Staffordshire University have now been joined by Universities at Aston, Cardiff, Derby, Hull, London South Bank and Teesside

[4] British Computer Society (BCS), Chartered Institution of Building Services Engineers (CIBSE), Institution of Chemical Engineers (IChemE), Institute of Measurement and Control (InstMC), Institute of Physics and Engineering in Medicine (IPEM), Society of Operations Engineers (SOE)

order to harmonise the processes of participants meeting their learning goals and meeting the competence requirements.

Each participant keeps a Professional Development Record of skill sets required and developed in the work-place and of experience gained. This is in order that the participant's evidence of competence can be provided to the PEI on an on-going basis. The PS ensures that this happens by checking the record, asking appropriate questions and making suitable suggestions for future activity. Most PEIs have an on-line monitoring system so that such evidence is available to members of staff and PEI professional advisors on an on-going basis: for example the electronic Monitored Professional Development Scheme (eMPDS) of the IMechE, Career Manager of the IET and the on-line professional development scheme of the RAeS which is run in conjunction with the Engineering and Technology Board.

The Professional Supervisor has the majority of the face to face contact with the participant. Subsequent to each visit to the participant the PS writes a Visit Report about the progress (or lack of it) in closing any competence gaps that the participant has made since the last visit. These Reports are counter checked by a 'Lead' PS who is very familiar with the participant's PEI, and their requirements. Finally these reports are sent to the University to be lodged in the participant's electronic records. Currently Kingston University is trialling new systems with the IET and the IMechE. The reports and any other documents relevant to the participant's progress can be uploaded and stored in a document vault: in the case of IMechE, the eMPDS system. They will therefore be available for the PEI to examine prior to the PRI, to see the progress made.

PSs attend a training conference each year. The first was held in Peterborough at Perkins Engines last year and others are planned for later this year. Its purpose is to review the processes of competence monitoring, mentoring practices and to ensure that all PSs know how matters are progressing at each PEI.

V. The pedagogy of work-based, problem-based and active learning

Work-based learning is only one of a number of terms that have recently become popular to describe newer alternatives to traditional classroom based pedagogies, such as active learning, problem-based learning, action research, etc. Although there is very little agreement amongst educationists as to the meanings of these terms, there is even less agreement as to their effectiveness. Generally the outcomes of research are inconclusive with no significant evidence of these newer approaches being more effective for student learning. However, there is evidence that their use does generate enhanced student engagement; in particular, problem-based learning can improve student ability to retain information longer and develop their enhanced critical thinking and problem solving skills [2].

The work-based learning methods used in the MSc Professional Engineering programme are actually a complex mix of many different methods, and the make up of that mix can vary significantly from one participant to another. Primarily it is a combination of:

- active learning [6], where the participant is positively doing something, and
- problem-based learning where the participant is positively doing problem solving,

Significantly:

- they are doing it in their own work place.
- it is self-directed learning, and
- the participant has the major responsibility for:
    - designing their own learning activities, and
    - ensuring progression.

Another very important facet of the programme is that is a mechanism for:

- lifelong learning,
- widening participation, and
- employer engagement.

The open and flexible nature of the programme allows people to undertake learning at any stage of their life. The accessibility of the programme enables people who otherwise would feel reluctant to engage with higher education, or could not afford to engage, to gain safe and affordable access to it. The programme's learning content is directly related to the employment work place activity and the employer is a direct partner in the learning, thus ensuring the learning is far more likely to meet employers' needs.

The programme has been developed because it will allow many engineers who otherwise could not develop their capabilities to their highest potential to do so in a way that is beneficial to both employers and the wider engineering community more generally. It has not been developed because work-based learning for engineers is a naturally better form of learning than traditional engineering programmes, (although we believe it certainly can be in many situations).

As such we believe it is probably the most appropriate form for most Chartered Engineers, and engineers working at that intellectual and technical level, for the highest level of critical thinking learning and development required as part of their continuing lifelong professional development.

The basic pedagogy for all participants on the programme, whatever the actual mix of their individual learning contract, is that of experiential learning, as first identified by Dewey [3] and then later developed Kolb [4], and widely known as "Kolb's experiential learning cycle", (fig.1).

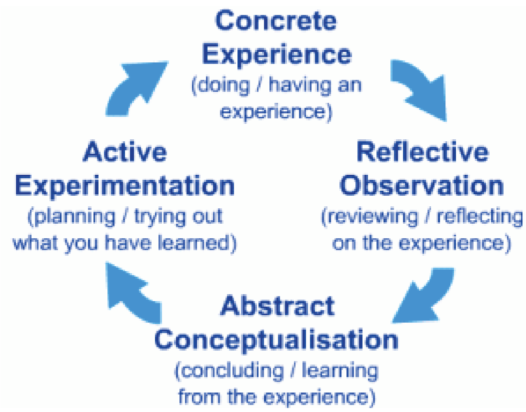

Figure 1

In this, an individual learns by going through four stages of the process:

1. Initially they have a "concrete experience", an interaction or real experience with some aspect of their environment. For our participating engineers this could be the action of implementing a new production line.
2. During or after the experience, the participant engages in "reflective observation" of:
   - what they experience
   - their actions within the experience, and
   - the responses of others to that experience.

   For instance they might try to:
   - analyse why they chose a particular solution to a problem they encountered during the introduction of the new production method,
   - describe what were the drivers of their decision making process,
   - explain how effective the problem solution was that they chose, and
   - ask, how did it impact on each other?
3. The third stage of the learning cycle is "abstract conceptualisation", which involves theory building in which critical thinking skills are developed to evaluate the reflections made about the experience. This for our participants is where the seat of in-depth learning takes place. It is the most challenging, because it requires participants to critically evaluate their existing understanding of engineering theory and practice. It may involve considerable independent study and research of technical theory, in order to be able to justify their actions, or alternatively change or amend their engineering knowledge and understanding to a new position as a result of their experience and independent study.
4. The final stage of the cycle is "active experimentation", where the theory that has been constructed is put to the test, by various means. For our participants this could be by:
   - deconstruction of their new knowledge and understanding into small testable packages,
   - the development of new working processes within their employing organisation for themselves and others, or
   - peer review as part of the MSc programme assessment strategy.

VI. The Role of the Professional Supervisor and the Underpinning Theory of Mentoring Used

The method of mentoring being used by Professional Supervisors is essentially one of assertive empathetic involvement. The closer the PS is to the student's work involvement, aspirations and professionalism the better his understanding of the participant's needs and competence development.

It is generally recognised that this form of mentoring enables:

- knowledge sharing
- working through of professional and personal issues
- improvement and career development
- support for study or research
- provision of a sounding board or critical friend when required

Mentoring [5] is help by one person to another in making significant transitions in knowledge, work or thinking
A mentor is someone who helps another to become what he aspires to be and helps another person through an important transition such as coping with a new situation or in career development.
By providing the means to share the knowledge, experience and advice of the Professional Supervisor, participants who have a keen desire to learn and develop themselves to achieve their goals.

One of the major objectives that the PS tries to achieve as a Mentor is to try and get the participant to 'think' like a Chartered Engineer. By that we mean not being afraid to 'question' an approach to a problem, or a technology suggested as a solution. Also we encourage them to adopt a more 'Strategic' outlook rather than a 'Tactical' approach "because it's always been done that way"!

Company or Industrial mentors are brought into the mentoring process alongside the PSs whenever necessary, whether it is to ensure contact and communication or whether it is to ensure harmony of purpose. It is very important to ensure that management processes within the company are not disturbed, so if there is a need to adjust the programme, then the PS needs to be very careful to put the participant's needs first within the company context.

The learning cycle described above is believed to be very powerful in both engaging engineers in further learning and in building continuing individual learning. However for many engineers, particularly those with many years practical experience it is not a process to which it is easy to take. Successful engineers are very capable in their area of expertise, confident in their understanding of their knowledge base whilst at the same time knowing the boundaries of their expertise, and very goal focused individuals.

It is not generally part of their make up to spend much time "navel gazing", which is how critical reflection is sometimes portrayed. The knowledge and understanding they build up is a mix explicit knowledge, that which is articulated and can we easily communicated, and implicit knowledge, that which is not (perhaps cannot be) articulated but is embedded deep within the engineer's engineering knowledge "know-how". It is often derived from experience where a key element is an ability to successfully apply knowledge gained in one field in an unrelated but similar environment. The accuracy or otherwise of this knowledge is therefore very hard to verify – and it is also hard to change.

In order to build continuous development and learning knowledge mining is required to seek out and incorporate implicit knowledge into explicit knowledge. This can be done concurrently with the "reflective observation and abstract conceptualisation stages of the learning cycle.

The role of the professional supervisor has therefore been constructed around a combination of the need to provide continuing ongoing professional direction to the participant in the progression of their learning contract, but also to engage the participant in critical debate, which challenges the participants' natural thought processes, and forces them to engage in critical reflection. It is this critical reflection which takes the participant through the reflective observation and abstract conceptualisation stages of the learning cycle. The ongoing critical conversation between the participant and professional supervisor is not one in which the learning is carried out by knowledge and understanding being passed from supervisor to participant, but it is a constant to- and fro-ing of ideas, in which engineering knowledge is the focus of the debate, and its value and voracity is subject to exposure and judgement. The professional supervisor is the initial leader of this debate, but in time the roles will be reversed and the participant, by learning from example, will be able to take the lead and start to critically reflect on their own engineering knowledge and hence continually build and develop it through a combination of experience, study and debate. The engineering conversation can then spill out beyond the restricted supervisor participant arena and into the wider employer organisation arena. The participant engineer can then move beyond the phase of individual learner and onto becoming the champion of organisational learning.

The role of the professional supervisor is thus crucial to the success of the whole work-based learning activity. They need to be professional supervisors on two levels:

- to provide the full range of advice and guidance needed by the participant on their journey to professional status,
- to have a very professional approach to their own mentoring activity.

The group of professional supervisors all have to conform to a common approach, and mentoring processes, for their activities, underpinned by a group understanding of the nature and purpose of those activities. This is not a set of processes which can be uplifted from a standard publication on mentoring. This activity and its processes can only be constructed and defined by the professional supervisors currently involved in this MSc Professional Engineering programme. It is a challenging piece of work in itself that is asking of the professional engineers doing the professional supervision to embark on considerable experimentation, reflection and theory building themselves. Progress so far has been very positive, with supervisors having produced working processes, performance and progress monitoring methods and arrangements for mapping academic working tasks against engineering competence standards. Work is ongoing toward a set of materials for the training and development of new professional supervisors, and this paper forms part of our activities to draw in the opinions and knowledge of others who can and would wish to contribute to this development.

VII. PROGRAMME EVALUATION

In order to provide reliable evidence of the effectiveness of this programme an evaluation process has been incorporated into the development project.

Initially prior to the start of the programme and during its development phase a survey was undertaken of engineering graduates who had completed an accredited engineering first degree between 2002 and 2006. The objective of the survey was to investigate the reasons why a very large proportion of engineering graduates did not progress onto professional registration.

The results of this survey [7] were surprising. In regard to furthering engineers learning to Masters Level, there was:

- no perceived deterrent in the additional costs of undertaking further studies, but:
- a lack of awareness of how to develop their knowledge to the requisite level.

In regard to Chartered Engineer registration there was:

- no perceived lack of support from employers, but:
- a lack of understanding as to how to progress.

Now that the programme has been running for two years a further investigation is being undertaken as to how well the programme has met the needs of engineers in these two areas, and to how well it is also meeting the needs of employers in helping them increase the capabilities of their engineers.

Initial feedback statements received so far from both employers and participants have all been positive and encouraging.

A number of case studies of individual participants' programmes which are relevant and illustrative of the initiative have been produced. These are available for distribution.

VIII. Employer Organisations involved

A number of large engineering employers have sent small cohorts of engineers on to the programme to evaluate its potential for helping them meet their forthcoming engineering development needs. The majority of the engineers on the programme are employed within large companies but 25% are employed by small or medium sized enterprises or companies (SMEs). The availability of university-provided professional supervisors is particularly important for those in SMEs because they would be very unlikely to be able to get appropriate mentoring from Chartered Engineers within the company.

The majority of the participating engineers are between 25 and 35 years old. Many of these are qualified with an accredited first degree and are using the programme to speed up their progress to Chartered Engineer status as part of a career development plan.

However a significant minority, 23%, are aged 36 or over. For these engineers:

- the programme provides an opportunity to enhance their own engineering capability and develop additional job satisfaction and personal goal achievement.
- the availability of a highly qualified professional supervisor is of particular importance in enabling them to engage in critical dialogue with a peer who can independently challenge their embedded engineering assumptions.

In total 30% of participants starting the programme have non-traditional entry qualifications. Again for them the availability of a professional supervisor is important in helping them to bridge the divide between their generally practical engineering development and the academic requirements of a Masters Degree learning programme.

IX. International Involvement.

Currently we are in serious discussions with a number of globally based multi-national companies who are very keen to adopt this approach to enable many of their senior engineers, based outside the UK, to become Chartered Engineers through UK PEI's. As these members of staff are based abroad the current ways of supporting them with both the Academic and the Professional Supervisors have to be re-thought.

Thus a new support and mentoring approach is being formulated which will involve enlisting the help of locally based senior engineers, trained by and working on our behalf, giving some Mentoring support and undertaking evaluation for us. This would be supplemented by visits by the PSs twice a year for more intensive and more in-depth reviews with each of the participants. To be cost effective for both us and the Company we would also expect that a minimum of 6-8 participants be enrolled by each overseas-based company, and that they're available in a single location for these twice annual visits. We expect the first of these 'international' participants to be underway early in 2010.

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Cooperative work and continuous assessment in an Electronic Systems laboratory course in a Telecommunication Engineering degree

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Abstract— **Electronic laboratory courses offer the possibility to introduce some specific and transversal skills to the curriculum of the students who follow an engineering degree. This paper examines the methodology and assessment which are applied in the laboratory course of the subject "Electronic Systems" in the second year course in the Telecommunication Engineering degree from the Castelldefels School of Technologyy (Escola Politècnica Superior de Castelldefels, EPSC) at the Universitat Politècnica de Catalunya (UPC). During 14 laboratory weekly sessions of 2 h, students must analyze and design the analog and digital circuitry for an ultrasound-based distance measurement system, by means of several guided practices. Small groups of two or three students worked on a collaborative way, while the teacher acted as a guide to facilitate project comprehension and knowledge acquisition. The experience we describe corresponds to the Spring term of 2009, a period in which this methodology was applied to two small class groups of about 23 and 7 students respectively. This work studies the influence of the initial characteristics of the students and their time devoted to prepare the subject, on their academic performance. The paper finishes with a list of recommendations in order to improve students learning process and course assessment.**

Keywords- *Collaborative work, electronics engineering education, circuit analysis, circuit simulation*

I. INTRODUCTION

It is well known that main general skills that enterprises demand for graduates of engineering programs are: teamwork, creative thinking and communication. To accomplish these requirements class activities must be learner-centred and teachers must become guides in the learning process [1]. The variety of skills that engineering students should master is increasing. There are several pedagogical methods that have been adopted in response to these needs [2]. There is much research showing that students who work cooperatively obtain better results and benefits from their relationships far more than students who do so competitively and individually. Cooperative learning [3] is the instructional use of small groups for students to work together to maximize their learning and that of their peers. Among the advantages of working cooperatively in small groups we can mention that it reinforces learning and improves skills and social relationships. It is a way of making students active cognitively. There are different studies related to the laboratory classes in courses on electronic technology where active learning is promoted [4], [5], [6].

It is very difficult to be objective when assessing laboratory work. In order to tend to give an objective global mark to the students it is very useful to consider applying a varied set of evaluation activities.[7]. Therefore we should use a variety of assignments to measure achievement of student learning [3]. The evaluation of the subject would be continous and it should promote the learning process. The feedback during this process promote competence development.

The present work is focused on: methodology (cooperative work and portfolio) and continuous assessment applied in the laboratory classes of Electronic Systems in the second year course (year 2000 Curriculum) in the Telecommunication Engineering degree from the Castelldefels School of Technology. We try to assess not only the specific course content, but also cross-curricular skills like: effective writing, critical thinking, collaborative work, and information organization. Indeed, these are the basic ideas that we try to convey through the introduction of the student learning portfolio [8]. The correct acquisition of a given competence is demonstrated by doing. For this reason skill assessment must be done through the activities and laboratory assigments students carry out.

II. COURSE ORGANIZATION AND OBJECTIVES

The course Electronic Systems is taught during the first semester of the second year. It consists of 6 credits, 3 credits corresponding to theoretical concepts and 3 credits corresponding to laboratory practices. The dedication of the student's work to the course is about 112 hours, which spread over 14 sessions of 8 h per week, equivalent to about 4,8 ECTS. The course has both a theoretical and a practical component, being laboratory class attendance obligatory. Students perform 2 hours of weekly lectures (classes have a maximum capacity for 45 students) and 2 weekly laboratory practices (laboratories have a maximum capacity for 20 students). This study corresponds to the Spring semester 2009 which has taken into account 30 students, divided in two laboratory-groups of 23 students (Group A) and 7 students (Group B) respectively. This number of students,

This work has been sponsored by the UPC-SLT project: "Consolidation and enhancement of the web of resources of Digital Systems, to support content and language integrated teaching (CLIL) at the EPSC"

corresponding to each group, only depends on the registration procedure carried out during the beginning of the term. Because of the small number of the participants involved in the study it is difficult to generalize the results, but like in other studies with few students useful qualitative conclusions can be obtained [9] [10].

After completing the course, students will be able to:

- Explain the design flow of electronic systems based on microcontrollers: sensors and actuators, conditioning circuits, power supply calculations, SPICE-based simulations, error analysis, assembly language programming, etc.
- Assemble circuits of medium complexity to check their basic knowledge of circuit theory and skills in laboratory instrumentation and prototyping tools.
- Work cooperatively with other students in order to design and assemble an electronic system (an application project integrating a large part of the course content).
- Write technical reports characterizing the behaviour of the electronic system.
- Compare experimental results with simulations and theoretical concepts.

In order to facilitate the student's acquisition of all these specific and cross curricular skills, cooperative work and continuous and formative assessment of student assigments is applied.

A. Cooperative Work

In laboratory classes students are required to work cooperatively in order to increase the communication between group members and reinforce their interdependence. The first day of the class the teacher explains the objectives of the laboratory and the rules that must be followed. These practices are conducted in groups of 2 or 3 people. Although it would be preferable that these groups were heterogeneous [11] they were formed according to their preferences of friendship in order to avoid problems of making meetings outside the laboratory. Each practice group should have a notebook and a portfolio. The laboratory notebook consists of a spiral pad size sheet on which students record all the sequential information (connection diagrams of the assembly, numerical calculations, instructor explanations, etc.) gathered during the laboratory practice. Taking notes in this notebook tries to inculcate the habit of scientific work to the students. The aim of this approach is that they can faithfully reproduce all the practices of the course.

The portfolio contains both students' works and reflections about the way they have learnt in cooperation during the laboratory term. The evaluation criteria are held continuously over the laboratory assigments, thus, the portfolio shows the way the student abilities have changed or improved over time.

Each cooperative group has to understand that individual success will be achieved from group's success; students have to believe that they "sink or swim together" [3], so that each member must ensure that their partner has assimilated the concepts and skills for each practice. During laboratory sessions instructors ask questions to any of the students in the group randomly and the marks are assigned to the whole group. This assessment ensures that students take seriously this learning process and verify that anyone in the group knows how to answer teacher's questions.

Laboratory practices are intended to design the analog and digital circuitry for an ultrasound-based distance measurement system. At the beginning of each session, students, in groups, must show the preliminary study to the teacher, which involves answering a series of theoretical issues relating to the practice implemented in the current session. To ensure a maximum profit from practical laboratory classes it is essential that students undertake this assignment. The teacher highlights in situ the errors that students may have done; they are able to correct them immediately; and as a consequence, the group's final report is improved by this fast feedback.

At the same time, to the development of each laboratory practice, students should complete a simplified report per session of two pages during the last 10 minutes of the session. This report consists of a summary of the major activities performed in each session and contains several basic questions related to the preliminary study and the experimental activities. In addition, the students can add their reflections [9] and questions being raised during the development of laboratory classes. At the beginning of the next session, the teacher delivers the report corrected, which ensures that students analyse the successes and mistakes they have committed.

B. Evaluation Of The Laboratory Classes

The evaluation currently being applied in the EPSC and in many other Schools of the UPC is the formative assessment which consists in carrying out a continuous assessment throughout the course [12]. The teacher-student feedback, introduced by the formative assessment, permits to correct the imbalances that may occur during the course, adapting teaching classes to each situation. For this reason, students and teachers have regular information during the course about the teaching-learning process.

Activities in the laboratory have assigned a weight of 45 % of the global grade. In order to assure formative assessment, the final laboratory grade is based on the following items:

- Two reports (10 %). Written reports were collected in the middle of the term and at the end, corresponding to the analog and digital designs respectively.
- Laboratory work, preliminary studies, reports of each session and portfolio (25 %). It takes into account the functioning of the practice and the answers to questions from the teacher.
- An individual laboratory exam (10 %). This test takes place at midterm, and it is a reference to the teacher to find out if indeed the cooperative learning has been successful, because if so, the members of each group should obtain similar scores.

III. Academic Performance Achieved By Students and Student Time Devoted to the Subject

The academic performance achieved by students is related with the pedagogical methodology applied, but it is also influenced by the past of the students. For this reason, in order to know what type of students attended the laboratory, at the first class of the course the students filled in a survey which consisted of several questions related to: address, previous studies, admission mark to the university, coursed subjects related to electronics, etc.

Analysing the survey of the two laboratory groups we find that most students come from Barcelona or its surroundings. Most of them, 71 %, began their studies in the fall semester 2007, respect the 29 % that began their university studies in the fall semester 2006. Because this subject corresponds to the first semester of the second year, these percentages indicate that most of the students have failed some subjects of their degree for whatever reason and perhaps are not the most brilliant or not the most motivated to study to the expected level.

As we can see in Table I, most of the students come from baccalaureate: 73,3 % respect to 26,7 % who come from professional modules. The percentages are similar in both class groups. In group A the number of students who attend the subject for the first time (47,8 %) is slightly lower than the number of repeating students (52,2 %). However, in group B most of the students (71,4 %) attend the subject for the first time.

TABLE I. Distribution of the students in function of their previous studies and in function of repeaters and non repeaters.

Number of students	Non repeating students	Repeating students	Baccalaureate	Professional Modules
Group A (23)	11 (47,8 %)	12 (52,2 %)	17 (73,9 %)	6 (26,1 %)
Group B (7)	5 (71,4 %)	2 (28,6 %)	5 (71,4 %)	2 (28,6 %)
Total (30)	16 (53,3 %)	14 (46,7 %)	22 (73,3 %)	8 (26,7 %)

In Table II it is interesting to note that the percentage of students that have passed the subject is slightly higher for those that have coursed baccalaureate (68,2 %) than for those that have coursed professional modules (62,5 %). The highest percentage of pass rate is attributed to those students who repeat the subject (71,4 %).

On the other hand, if we center our study on the laboratory exam (done in the 8th week), we can see that these percentages decrease significantly (43,3 %), except in group B where remain the same (Table III). Although both groups have few students, this result confirms that generally, smaller class groups have a higher pass rate than more numerous groups. This can be attributed to the fact that in group B a higher percentage of students attends the subject for the first time. Furthermore, subjective observations made by the teacher showed, in percentage, a higher motivation of laboratory work for students of the group B.

TABLE II. Distribution Of The Students That Have Passed The Subject.

Students that have passed the subject	Non repeating students	Repeating students	Baccalaureate	Professional Modules
Group A (14) (60,1 %)	5 (45,4 %)	9 (75 %)	11 (64,7 %)	3 (50 %)
Group B (6) (85,7 %)	5 (100 %)	1 (50 %)	4 (80 %)	2 (100 %)
Total (20) (66,7 %)	10 (62,5 %)	10 (71,4%)	15 (68,2 %)	5 (62,5 %)

Like in the global pass rate, we observe that baccalaureate students have a slightly higher pass rate than professional modules students, but in this case repeaters and non repeaters obtain very similar results. A possible interpretation could be that the practical exam only consisted on theoretical questions respect to the practices. If it had included some practical exercises using the instrumentation and assembling circuits it is possible that students who came from professional modules would have obtained better results. Time devoted to solve the exam is another aspect to take into account, because more time you lend to students better results they would obtain.

TABLE III. Distribution Of The Students That Have Passed The Laboratory Exam.

Students that have passed the lab-exam	Non repeating students	Repeating students	Baccalaureate	Professional Modules
Group A (7) (30,4 %)	2 (18,2 %)	5 (41,7 %)	6 (35,3 %)	1 (16,7 %)
Group B (6) (85,7 %)	5 (100 %)	1 (50 %)	4 (80 %)	2 (100 %)
Total (13) (43,3 %)	7 (43,8 %)	6 (42,9 %)	10 (45,5 %)	3 (37,5 %)

Another parameter of interest in our study is the distribution of students according to their admission mark to the university (Table IV). After processing the data, we see that most of the students are concentrated in the range of marks between 5 and 7. A number of 25 responses were processed because 5 students didn't inform about their admission mark in the first questionnaire.

TABLE IV. Distribution of the students according to their admission mark to the university.

Number of students	[5,6)	[6,7)	[7,8)	[8,9)
Group A (20)	4 (20 %	11 (55 %)	4 (20 %)	1 (5 %)
Group B (5)	1 (20 %)	3 (60 %)	1 (20 %)	-
Total (25)	5 (20 %)	14 (56 %)	5 (20 %)	1 (4 %)

Tables V and VI show an interesting result: there is no direct relationship between the admission mark and the subject pass-rate. In this sense, we can observe that the pass-rate is higher for those students who entered with the lower admission mark. This result contrasts with the one found in [12], where this correlation was shown to be higher, because the analyzed subject corresponded to the first term of the first year course of the degree.

TABLE V. DISTRIBUTION OF THE STUDENTS WHO HAVE PASSED THE SUBJECT ACCORDING TO THEIR ADMISSION MARK TO THE UNIVERSITY.

Students who have passed the subject	[5,6)	[6,7)	[7,8)	[8,9)
Group A (14)	4 (100 %)	7 (63,6 %)	3 (75 %)	0 (0 %)
Group B (4)	1 (100 %)	2 (66,7 %)	1 (100 %)	-
Total (18)	5 (100 %)	9 (64,3 %)	4 (80 %)	0 (0 %)

TABLE VI. DISTRIBUTION OF THE STUDENTS WHO HAVE PASSED THE LABORATORY EXAM ACCORDING TO THEIR ADMISSION MARK TO THE UNIVERSITY.

Students who have passed the lab-exam	[5,6)	[6,7)	[7,8)	[8,9)
Group A (7)	3 (75 %)	3 (27,3 %)	1 (25 %)	0 (0 %)
Group B (4)	1 (100 %)	2 (66,7 %)	1 (100 %)	-
Total (11)	4 (80 %)	5 (35,71 %)	2 (40 %)	0 (0 %)

Table VII shows the average marks of all items of the continuous assessment of the laboratory work. In addition we present the average marks corresponding to the two theory exams that are done in the midterm and at the end of the course. It can be seen that laboratory work and reports are the items with highest marks and the exams are the items with lowest marks. Students of group B have obtained higher marks than students of the group A on all evaluation items what agrees with instructor observations during the laboratory work. A consequence of this is that students rely on laboratory classes to pass the course, which diminish the pass-rate in exams.

TABLE VII. AVERAGE MARKS OBTAINED IN EACH ITEM OF THE CONTINOUS ASSESSMENT.

Average marks	Group A	Group B
Final mark	4,4	5,3
Reports	6,3	7,5
Laboratory-work	6,4	7,4
Laboratory-exam	2,3	5,9
Theory-exams	2,9	3,8

A possible cause to the low final average mark achieved by the students could be that they didn't spend enough time doing the activities and studying the different topics of the course. For this reason students were asked to evaluate during 8 weeks of the course (randomly selected) how much time they had spent studying for each session (both theory and laboratory classes). The results have been that in average, the students of the group A have employed 3,48 h/week and 3,61 h/week preparing theoretical and laboratory classes respectively. In group B students have spent 3,24 h/week and 4,33 h/week respectively. It should be noted that these times include the activities inside and outside of the class. They have spent more time preparing laboratory practices than studying theoretical ones, what is reflected in the lower marks of theoretical exams. These results are slightly lower to the instructors' previsions of 4 h per week in average.

Fig. 1 shows the relationship between the average of hours per week that each student of the group A devote to the whole subject and the final mark obtained. The time value that appears in the figure is the average of theoretical and laboratory work per week, that approaches 4 h. Fig. 2 corresponds to the time devoted by students of the group B. In both groups, we don't see a direct relation between the pass rate of the students and their time devoted to the subject. The correlation coefficients have a low value: -0,2907 and 0,3345 respectively.

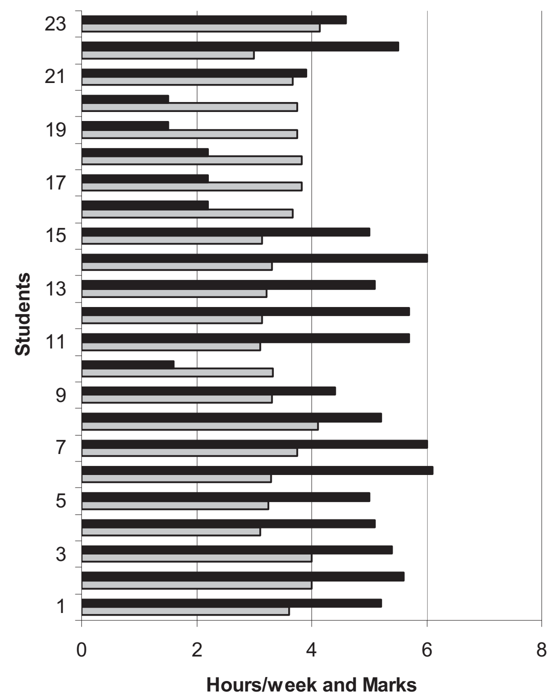

Figure 1. Average time devoted to study the subject (grey) and final mark (black) obtained by each student of Group A.

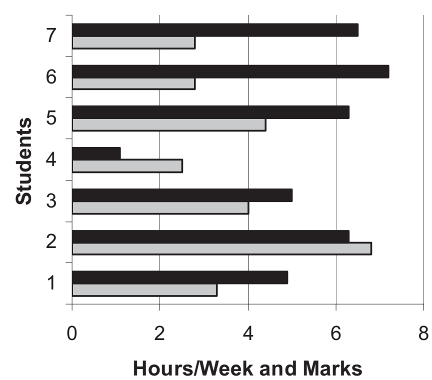

Figure 2. Average time devoted to study the subject (grey) and final mark (black) obtained by each student of Group B.

IV. Final Feedback and Future Improvements

To collect the student's views about the teaching process and to get feedback from them, an adaptation of the Student Experience of Education Questionnaire (SEEQ) was carried out at the end of the course. Around 19 students took part in the survey. In Table VIII we have selected some of the most representative questions we have raised in the two class groups. Students were asked to punctuate each question in a scale from 1 to 5, as: 1. Strongly disagree, 2. Disagree, 3. Neutral, 4. Agree, 5. Strongly agree.

TABLE VIII. SEEQ QUESTIONNAIRE. MOST REPRESENTATIVE QUESTIONS, RELATED TO THE METHODOLOGY APPLIED IN THE COURSE.

Questions	**Group A (16) (70 %)**	**Group B (3) (43 %)**
I have also learned more English, to work cooperatively and make oral presentations	2,94	2,33
The teacher has been dynamic and active during classes of group work and has followed our work	3,88	3,67
Classes have been clear and the explanations have been a good material for understanding the subject	3,94	4,33
Course material was well prepared and has been carefully explained	3,94	3,67
Group work in classes timetable has been useful and well organized	3,87	4,33
The classes of group work that we have organized outside the regular timetable, have been profitable and useful	3,88	4,0
Cooperative working groups have been a good tool to study and learn the subject and share knowledge and ideas	4,06	3,0
Instructot's comments on the corrected work and exams were very helpful	3,69	3,33
The methods of evaluation of this course are fair and appropriate	3,81	3,33
The contents of examinations and other evaluated assignments, correspond to the course contents, in accordance with the emphasis placed on each subject by the teacher	3,69	4,0
The portfolio helped me to organize my study during the course	3,44	4,0
The workload of this course compared with others, has been: very small (1), Small (2) Normal (3) Great (4) Very large (5)	3,56	3,5
I would recommend cooperative learning in other subjects of the grade	3,50	3,0

It can be seen that all items are well punctuated, with average marks of 3,71 in the group A and 3,58 in group B, what indicates that student valuation of this methodology is good.

From the analysis of the results relating to the academic performance and taking into account the feedback received by the students, some improvements that we propose for future laboratory courses are:

- In order to be more objective assessing each student individually it would be useful to give them some written questions, five minutes before the end of each laboratory class. These basic questions could be drawn up in English, because it is an important cross-curricular to be introduced.
- The laboratory exam should include not only theoretical questions but also practical experiments. It would be done at the end of the term instead of the midterm, in order to take into account not only the analog block of the electronic system but also the digital block.
- Although some groups did very well write portfolios, we consider that too little time was reserved to assess the portfolio, because some groups collected the information few days before was presented to the instructor. Students would consider more important its realization if it was graded highly in the assessment process.
- Although the good quality of some written reports collected at the end of the analog block and at the end of the digital block, we have observed some plagiarisms. They could be avoided giving a more detailed writing model to follow, which can be changed from one course to another.
- In order to improve theory exam grades it would be very interesting that laboratory assignments were more related with theory contents and vice versa.
- Students should complete a report about their collaborative work during group meetings done outside the laboratory, in order to reflect about this active learning methodology, when the instructor is not present.

V. Conclusions

This paper has analyzed the ongoing methodology and assessment which have been applied in the laboratory course of the subject "Electronic Systems" in the Telecommunication Engineering degree from the Castelldefels School of Technologyy (EPSC). The experience that we have described corresponds to the Spring term of 2009, a period in which the authors of this work have studied two laboratory groups of about 23 and 7 students respectively.

This work relates the academic performance with the initial characteristics of the students, obtained from the analysis of the responses to a questionnaire that was given to the students the first session of the course. The highest percentage of students who passed the subject occurred in students coming from the baccalaureate or who had repeated the course and no clear correlation between overall academic performance and admission mark to the university was observed.

Students were asked to evaluate how much time they had spent studying for this course. Taking into account the information given by the students and the marks obtained, we conclude that they don't spend enough time preparing the subject. This study also shows that the relationship between the time devoted to prepare the subject (inside and outside the class) and the marks obtained by the students are not correlated. Although there is no direct relationship between time and marks, some students would improve results if they made a more effort.

If instead of applying the continuous assessment, we only took into account exam grades (theoretical and practical), the pass rate would have been lower. Increasing better grades in exams is a challenge for future courses.

Continuous assessment and collaborative work improve the performance of students less prepared, but hinder the emergence of endnotes brilliant, because it is very difficult to get very good grades in all evaluation criteria.

Although academic performance should be improved, most of the students have had a favourable impression of the methodology applied in laboratory classes.

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Intelligent evaluation in educational context

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Abstract— **The idea is to conceive an intelligent computing system of decision-making aid, in this context of teaching training, the quantification of the human behaviors is the key to this system's innovation. Seeing that it gives opportunity of measuring the professional acts of the teachers in class. This makes it possible to locate these practices compared to the pedagogical theories, into force and especially compared to the constructive approach. In addition, this system helps to identify the student's styles of learning; therefore it places, at the disposal, information which facilitates to the teachers the adaptation of their pedagogical methods so that the student benefit a maximum assimilation. For what concerns them, the students also profit from an innovating alternative: result of the web based performances analysis in summative evaluation. It is a generated report, for each pupil, automatically at the end of the seizure of the marks stipulating in details their weak points and specifying the adequate remedies in terms of activities to be realized to proceed to reflexive regulations in order to raise their levels of assimilation. An able system, starting from observable behaviors in classrooms and of performances seized remotely via the Web, to quantify in a rational way the cognitive and emotional states of the actors of the context of teaching training. An expert system whose general objectives would be: classifying the profiles of the teachers starting from their professional competences based on their pedagogy, behavior and attitude, classifying the learners' profiles by analyzing their interactions and analyzing their performances in summative evaluations, adapting the resources of the teacher's pedagogical methods in order to have a better coherence with the profiles of identities, the profiles of motivation and the profiles of comprehension of learner.**

Keywords-component; ***Evaluation, statistics, learner profile, teacher profile***

I. INTRODUCTION

The world in which we live witnesses the birth of expert systems which aim to classify and assist with the decision making whose complexity increases with the development of the tools, of the techniques related to decisional data processing. This observation is not limited to technical field but also related to the educational field and more precisely to the diagnosis and the evaluation of the process of teaching training. On the basis of a medical vision, the diagnosis is an activity of identification of the causes of a physical or human system's dysfunction starting from the observation of its revealing symptoms. Frequently, the dysfunctions are diagnosed starting from a whole of associated symptoms named characteristic syndrome. The relevance of the diagnosis is strongly dependant on the complete observability of the device.

We could, also, add that the etymology of the diagnosis term means "knowledge through signs". Therefore, a diagnosis of the profiles of the actors of teaching training can be interpreted as the knowledge of the cognitive state of the actor (teacher and/or learner) of the context through his actions and his reactions at the time of an activity of teaching training.

From there the idea to conceive an intelligent computing system of decision-making aid, in this context, which is a reliable tool in the hands of the secondary education's inspector. A system able to manage the variable characteristics of the learner and the teacher in order to facilitated a reliable decision making of what must be recommended for each whole of circumstances, thus avoiding the recourse to the intuition and subjective and nondescribable decision making in deterministic terms. An able system, starting from observable behaviors in classrooms and of performances seized remotely via the Web, to quantify in a rational way the cognitive and emotional states of the actors of the context of teaching training. An expert system whose general objectives would be: classify the profiles of the teachers starting from their professional competences based on their pedagogy, behavior and attitude. Classify the learners' profiles by analyzing their interactions and analyzing their performances in summative evaluations. Adapt the resources of the teacher's pedagogical methods in order to have a better coherence with the profiles of identities, the profiles of motivation and the profiles of comprehension of learner.

The organizational structure of this expert system is hybrid. Indeed, it is computer software installable on the laptop of the inspector and whose entries are seized, on the one hand, in class by the inspector. He interacts with the system using an interface man machine based on grids of teaching and didactic functions which we will detail later on. On the other hand, the marks of the students' summative evaluations are collected by the remote system starting from a Web site placed at the disposal of the students.

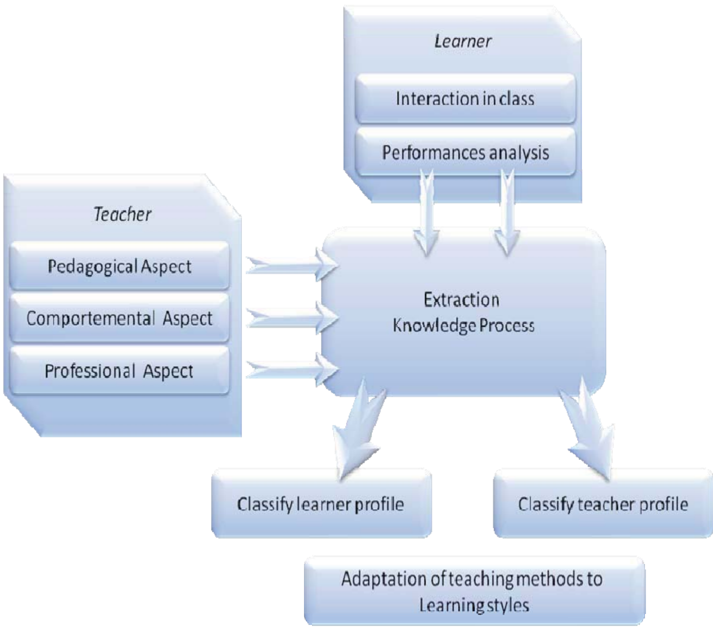

Figure 1

II. DYNAMIC EDUCATIONAL PROCESS OF LEARNING SEQUENCE

In trying to identify the key factors that characterize the various approaches that define the learning, we find that the role of students is essential. In constructing his knowledge that he built himself and who is constructing, acquiring knowledge. This interactive process of teaching and learning is modeled by Marcel Lebrun following five categories.

Figure 2

A. *The steps of a teaching learning sequence*

We began a sequence of teaching-learning by encountering a new situation, a problem suitable for students connected with circumstances known to them, so it presents a real opportunity to gauge their own prior knowledge and skills. And since meaning is given through structure, there is no shortage of ways to provide understanding of the structure to access the significance. This context would be motivating if it leads the student to give a value to the task, it is proposed by identifying the elements, facts, transactions that make sense and meaning. On the other hand, this context has an evocative power and potential for expansion because of its direct contact with reality, experience, applications, and needs: it causes management and control by the student.

The next step illustrates the importance of access and information gathering. Thus, we proceed to harvest information from the context, the views of students and their different representations, resource centers are meeting places, information is contextualized. This is mapping between world and formalism.

The analysis phase is gradually learning to learners to build tools for information retrieval, structuring, comparing, categorizing and confrontation. It means developing the ability to manipulate the world descriptions, relating and manipulating the various form of representation.

The stage of interaction operates the interactive and collaborative learning, emphasizes the importance of factors relating to communication and teamwork, and since action without feedback is unproductive for a learner, we use feedbacks intrinsic versus extrinsic or action in relation to representations, which allows the student to recognize his abilities.

Finally, the production stage that leads to reflection not confined to the goal but as aspect of the whole learning process. It illustrates the importance of personal production, creative activity, the role of self-assessment, promotion of change and reflection "meta" learning how to learn. It is a step of recontextualization in which the student builds something personal.

III. TEACHERS' ACTING PROFILES

The educational relationship is a set of verbal and nonverbal characterizing the act of teaching. These exchanges are affected by teaching methods practiced by the teacher. DeLandsheere and Bayer have classified these exchanges in seven categories, called pedagogical functions that cover the key events of school life. Each educational function is characterized by a set of measurable actions which, once identified, resulting in their existence and sequencing the action plan of the teacher, his rational way to organize a practical rule of advance operations to accomplish. This awareness comes not only from theoretical knowledge but especially from the implementation of this knowledge in the field.

A. Pedagogical assessment

The organizing function that sets the conditions and context in which the act of teaching-learning must be given. Imposition function is for the content of education or starting framework facilitating stimulation. The development function designed by educational and teaching techniques used by teachers to ensure the development of intellectual and psychomotor abilities of the student. The personalization function uses the previous knowledge and representations of student achievements, including his own difficulties. The function of positive and negative evaluation that informs students of the quality of its performance, positive and negative affectivity related to the student personality, eventually, the realization function that characterizes the teaching aids and technical visual, auditory used to channel information to the student to achieve an optimal acquisition of knowledge.

Each measure of verbal and nonverbal teacher’s act must be categorized to the proper pedagogical function; the corresponding time periods must be measured during the course of the activity. An acquisition tool is designed, offering a friendly interface formed by the grid functions and its criteria. A simple click on each criterion detected in the act of teaching that the algorithm accounts for the periods corresponding acts, it collects and makes the combined category. The data collected is stored in a spreadsheet. This algorithm has been validated in advance before its systematic use to ensure its adequacy and accuracy is sufficient.

As a first approach, we opted for the visualization of statistical results in the form of histograms in a plane with two axes representing teaching functions on the horizontal axis and the cumulative final frequency on the vertical axis. This has an

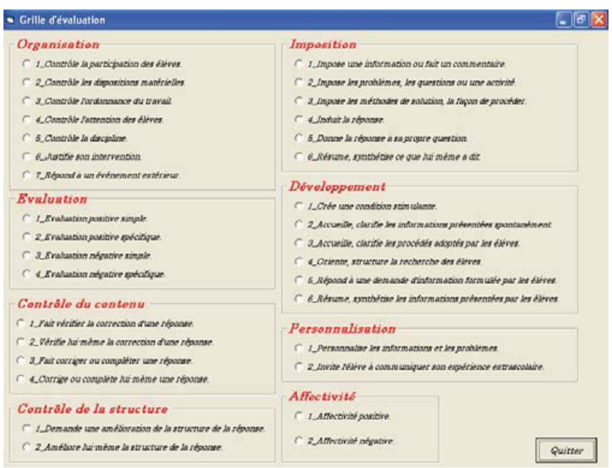

Figure 3

effect not only on visualization of comparative quantities frequencies educational functions between them, but especially between the same functions measured at successive visits.

B. Behavioral assessment

Since the teacher is not perceived by its students solely on the cognitive but also in terms of personality: "we teach what we know with what we are”, it would be appropriate to conduct assessment of attitudes, behaviors and methods of teaching, especially that within his personality, the same order is preserved if we go from what is the most spontaneous to what is more built as finalized and The more organized.

Behavior estimation scale

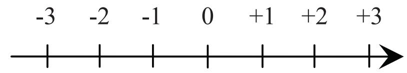

TABLE I

<table>
<tr><td>Distant</td><td rowspan="8">Behavior estimation scale</td><td>Available</td></tr>
<tr><td>Narrow-minded</td><td>Comprehensible</td></tr>
<tr><td>Hard</td><td>Kind</td></tr>
<tr><td>Dull</td><td>Stimulating</td></tr>
<tr><td>Stereotype</td><td>Original</td></tr>
<tr><td>Indecisive</td><td>Confident</td></tr>
<tr><td>Excitable</td><td>Sedate</td></tr>
<tr><td>Disorganized</td><td>Methodical</td></tr>
</table>

C. Teaching methods

As teachers, the more we know about how our students think and learn, the more successful we will be at helping them realize their educational goals. Teachers are learners too, and we often use teaching methods in our classrooms that complement our own personal learning styles. Our teaching styles may not be effective for our students, who may have learning styles that are very different from our own. There are many ways to assess learning style preferences for our students (and for ourselves): most of these methods rely on the use of diagnostic learning style preference “tests” that are based on one of the learning style models (Myers-Briggs Type Indicator, Kolb’s Learning Style Model, Herrmann Brain Dominance Instrument, Felder-Silverman Learning Style Model).

A teaching method describes the pedagogical means adopted by the teacher to enhance learning and achieve its educational objective. The teacher values over a given time one method than another, at the discretion of the teacher is often a matter of circumstances. To facilitating learning and mediation of knowledge, it is important to review regularly the method of teaching. It is customary to distinguish five teaching methods: expositive, demonstrative, interrogative, discovery and experiential. They can be practiced in a teaching sequence or individually or in small or large groups with the mediation of educational tools.

With transmissive method, the teacher has skills in a structured content and transmit knowledge in the form of presentation, the lecture that leaves little place for interactivity with the learner. In the didactic triangle, this corresponds to the relationship teachers - knowledge where the teacher is an expert of the content, a keeper of truth, which transmits information unambiguously.

The teacher determines a path teaching in demonstrative method: he shows, he makes doing and then make the student to formalize in order to assess the degree of understanding. This method is often used to make the student acquires skills through simple imitation.

Within interrogative method, the student is recognized as having elements of knowledge or representation of content acquisition. Using appropriate questioning, the teacher allows students to construct knowledge by himself or to make connections and make sense of these disparate elements. The student or student group is encouraged to formulate what he knows, what he thinks, what he represents

The teacher creates a scenario, when using an active method, with educational materials that can use trials and errors to learn. He mobilizes the experience of the student or of a group of students to assess the situation and solve the problem with their means. Intracognitif and co-development work between peers is promoted.

Many disciplines or knowledge can be taught but learned by doing with people who can do such as, medicine or art. This knowledge is gained by the student in and by the action in a real project. The teacher encourages the formalization of knowledge by the student who is the real producer of knowledge sharing and re-elaborates it with others. This is what is called experiential method.

IV. STUDENT'S LEARNING STYLES

For any academic training, the learner is implicit target, around which is built a huge process to make him, explicitly, the main actor. It must therefore be identified by our system on different plans and different levels. Beginning with a thorough study of its intelligence and its many facets that make up the dynamics of cognitive development, types of interactions with his teachers, peers, the learning content, technology media in use, and its environment. An environment that must demonstrate its social presence is the result, among other things, of its interactivity and its affectivity. His cognitive presence outcome of the accommodation of its prerequisites with new knowledge and assimilation. Self-regulation and self-evaluation are also identifiable skills in the learner through various indicators which converge, too, with those of his learning style. We consider motivation and attention of the learner in order to be able to "detect" at will during the teaching learning sequence through their determinants in order to maintain an optimal level and maintain it.

Learners are intrinsically different and have different preferred learning styles. Learning styles indicate the way people prefer to "receive" information, they address the learner's preferences for the learning environment and his modality preference. Mc Carthy identifies within his research four student's learning styles. First, innovative learners who are interested in personal meaning of knowledge, they need to have reasons for learning. Reasons that connect new information with personal experience and establish that information's usefulness in daily life. Second, analytic learners who are interested in acquiring facts in order to deepen their understanding of concepts and processes. They learn effectively from lectures and they enjoy independent research, analysis of data, hearing what "the expert" has to say. Third, common sense learners, they are essentially interested in how things work, they want to "get in and try it", they learn effectively with concrete experiential learning activities using manipulative, hands-on tasks, Kinaesthetic experience and so on. Finally, dynamic learners who are interested in self directed discovery, they enjoy simulations, role play and games.

The modalities of those learning styles are subdivided into four categories. Visual verbal learning style in which information is presented visually in a written language format. Visual non verbal style, information is presented visually and in a picture or design format. Students with this modality of learning, benefit from teachers who use visual aids such as film, video, maps and charts. They may have an artistic side that enjoys activities having to do with visual art and design. Students with tactile kinaesthetic learning style learn best when physically engaged in a "hands on" activity. They benefit from laboratory setting where they can manipulate materials to learn new information. Learners with auditory verbal learning style learn best when information is presented auditory in an oral language format, so they interact with others in a listening speaking exchange. They benefit from listening to lecture and participating in group discussions. When trying to remember something, they can often "hear" the way someone told them the information, or the way they previously repeated it loud.

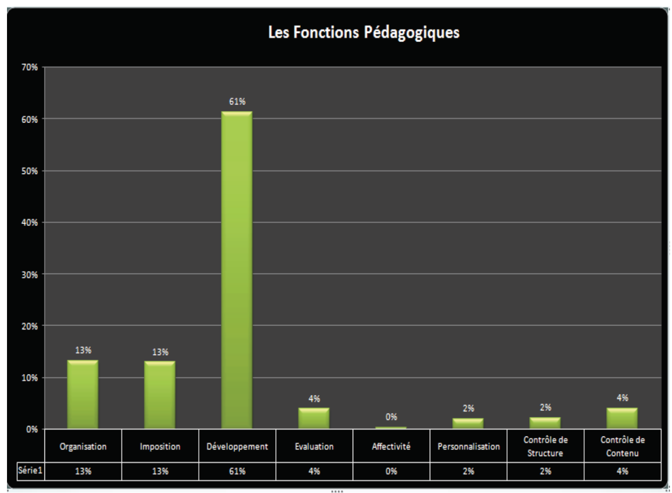

Figure 4

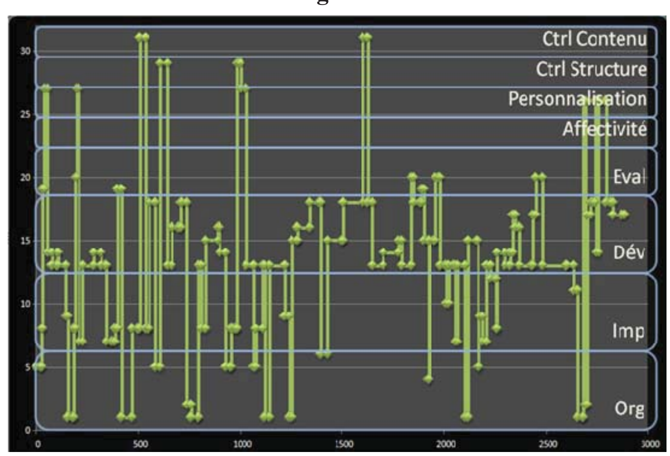

Figure 5

V. Results

The evolution of the teacher's practices in class will decrease school failures enormously and will support a relevant educational insertion. This evolution is the result of the reflexive practices that the professor starts as soon as he has between his hands the static recordings of his professional practices in the forms of histograms. These histograms illustrate the cumulated rates of the teaching pedagogical functions. The teacher can read measurements of his acts and discriminate those which are harmful with any active way. A way with it the teacher plays the part of an organizer, facilitating the access to knowledge which is built by the student in an autonomous motivating style. The teacher can also read the evolution of his practices during the time of the course: it is the dynamic aspect of the recording.

VI. Conclusion

Teachers have experienced a major interest to the various statistics generated at the point where they cheered as soon as the course ended and they often inquire about the meanings of educational functions whose performance is lacking. There is even that in many cases, following a second visit, the development function becomes more dominant than that of imposition. We also note that personalization appears, negative affectivity is substituted with positive one. In some cases, especially for older teachers, they find it difficult to assign the practice of imposition in favor of one that is developed. Despite this, one finds that the development practices evolve without the knowledge of the stagnation of imposition. All teachers visited, old or young, have been manifest in their professional practice developments relating to acts that promote centering on the student in performing their function of teaching learning. Changing teaching practices in the direction of better focus on the pupil, following the identification of their past practices by the evaluation grid used.

One of the challenges which threaten more the educational world and especially the secondary and academic levels is the uninspired pupils. They do not take any interest in what occurs in class and they give up every attempt of fixing to the course of their learning dice the slightest difficulty. The situation is still worsened with the feeling of routine which invades the professor at the time of his practices in class. In this work method and with the instructions of assistance which the expert system generates, the professor and the pupil are in harmony in the classroom. The teacher recognizes his pupil well by adapting his manners to him; the pupil is suitably framed with the feeling of being the Master of the situation who can construct in an autonomous way his knowledge.

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Meaningful learning checking of concepts related to equations and functions in physics chemistry according to the main theme gas law

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Abstract — **In this article, the authors propose an investigation of the learning process of the concepts and of the mathematical relations in the physical chemistry study of the gas, mapping an interdisciplinary teaching approach. The theoretical background of the research is based on the Theory of Meaningful Learning (ML) and on Gowin´s Epistemology trying to relate events, facts and concepts with other elements of knowledge through the "see" heuristic. The research experiments are being conducted with chemistry graduating students at the Universidade Federal de Pelotas in Rio Grande do Sul, during one semester, but it is planned to extend the studies to the engineering courses. The tests to check the subsumers are based on some theoretical questions related to the mathematical concepts already mentioned. Preliminary results of the testing show arithmetic and algebraic disabilities in a percentage of the group, as only 60% of the students answered the tests correctly. Based on the answers analysis contextualized activities are proposed to enrich the mathematics application in chemistry with the objective of favoring the development of the subsumers needed to the comprehension of the PC phenomena studied.**

Keywords- Physical Chemistry, Mathematics, Meaningful Learning, Interdisciplinarity

I. INTRODUCTION

Part of the subjects which composes the specific cycle of the engineering courses and of the chemistry graduation courses need some requirements from the mathematics area (calculus, analytic geometry, linear algebra), as it is the case of physics chemistry. On the other hand, an enormous challenge for the students of these graduation courses is to apply the mathematical concepts that were studied before in an isolated and fragmented manner, in the interpretation of the phenomena related to their area of knowledge.

At Universidade Federal de Pelotas (UFPel) and at Universidade Federal do Rio Grande do Sul (UFRGS), the physics chemistry subject has the characteristic of belonging to the Chemistry filed, but it is also part of the Engineering Courses specifically related to the Chemistry Engineering, Food Engineering and to the Metallurgical Engineering. The aim found in the teaching of this discipline to the Chemistry and/or Chemistry Engineering and to the other engineering courses is that for the first theoretical classes are realized while for the second the classes given are only theoretical. This fact does not allow the complete and adequate contextualization of the mathematical tools causing huge difficulties in their applications.

An optional approach that enriches the practical activities experienced and which has been more present in the graduation courses is related to the use of computer simulation, modeling and virtual reality software among others. The use of computational resources in the education field is related to activities that can potentiate the educational activity and that can add value to the teacher's work as technology and creativity integrate the new format of knowledge transmission. Besides, through the computational activities it is possible to potentiate the cognitive process of the students creating products that put together hypermedia as audio, video, simulations and animations.

In the field of engineering education, we emphasized the research of Zimmer *et al* [1]. Their studies suggest the development of a virtual laboratory of differential and integral calculus in order to contribute for the learning and teaching process in relation to the interest and motivation of students. First, the tutorial software was developed with concepts and definitions capable of solving some differential and integral problems. After, the students presented their works developed in panels during an exposition to the public. Finally, a webpage was created where all the content was organized to be accessible for anyone.

In respect to the teaching of electrical engineering, Vieira Junior & Colvara [12] call the attention to the difficulties that happen due to the huge need of abstraction of the phenomenon studied. This way, they propose the development of some educational software which allows the user to analyze different events of stability in electrical systems.

The authors suggest the use of this software as a helping tool in the teaching process emphasizing the graphics visualization in 3D which allows to put the images and to rotate them showing their view in different perspectives.

Our research tries to comprehend the difficulty of the students through the meaningful learning theory, in relation to mathematical knowledge (subsumers) needed to the study of the gas transformations to propose some software of computational simulation applicable in the physics chemistry subject. The studies were initiated with the realization of a pre-test in order to verify the mathematical knowledge that the students have about: the meaning of an equation, function, its differences and relations, independent and dependent variables, operations about the set of real numbers, quantities directly and inversely proportional and the applicability of mathematics in the chemistry area and, more specifically, in the ideal gas equation in the subject of Physics Chemistry I.

At the same time, interviews with the professors were realized in the Universities mentioned before in this article about the main difficulties found by the students in the applicability of the mathematical concepts. The interviews showed some common difficulties as: in the solving of equations, in the interpretation of inverse quantities, in the representation of functions, among others. One aspect told by the professors is related to the adequacy difficulty of the available graphical software in relation to the aim and needs of the specific subject of Physics Chemistry I.

The initial results of these practical studies indicate the need of developing a graphic simulator for the study of the Ideal Gas Law which will be showed later on this research, after the presentation of the theoretical background. After that the results of the use of the simulator will be presented and discussed and at the end the final considerations will be exposed.

II. TEORETHICAL

The development of the work was based on an investigative study about the learning and teaching process concerned with the Meaningful Learning Theory, its association with Conceptual Maps and the relation between them with Gowin's Epistemology, which are presented below.

A. *Meaningful Learning Theory*

The meaningful learning theory has as its assumption the fact that the student has some knowledge and he can use it as a mean to insert new information into his cognitive structure [5, 9]. According to author [6], the main points of the meaningful learning have as the main actor the student himself who learns when he finds sense in the concept presented and through the conceptual hierarchies which can be understood as the association or combination of new concepts to the ones that already existed before in the cognitive structure.

In the context of this work the concepts about equations and functions acquired by the students will be discussed. From this conceptualization the ideal gas equation will be inserted as the graphical representation of the gas transformations.

The knowledge structures through which the new concepts occur in the meaningful theory [4] sets as subsumers. They act as a support structure to join the new concept forming a new subsumer. The figure below shows this conceptualization.

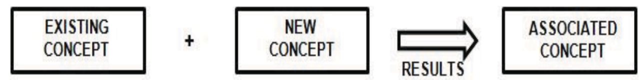

Figure 1. Concepts formation based on the subsumers existency

Source: the authors of this research

The initial process of verifying the meaningful learning consists in the identification of the existence of the subsumers. In this sense, the author [9] suggests the realization of a pre-test to check the existence of the subsumers needed. The pre-test is formed by questions related to the subject which it is intended to be verified and also the level of knowledge that the student has about it.

For the students who do not have subsumers, they are submitted to the advanced organizers, according to the meaningful learning theory. The use of advanced organizers according to author [4] is a way to manipulate the cognitive structure of the student so that he can be able to receive new concepts. The advanced organizers are made of new activities, more elaborated ones so that they can supply the need of the student, affirms the author [9].

B. *Conceptual maps*

In a broad sense, conceptual maps are diagrams that indicate relations between the concepts [11]. The conceptual map establishes the relation among concepts through key words in a non-hierarchical way. The key words can be short linking sentences, verbs, prepositions and also nouns, according to the Figure 2. More specifically, it reflects the conceptual organization of a subject or part of it. In other words, its existence is formed from the conceptual structure of a discipline and it can have two or more dimensions.

Moreira [10] proposes the conceptual maps as useful tools to promote the progressive conceptual differentiation and the integrative reconciliation, concepts present in the meaningful learning theory and he highlights its potential as an evaluation tool over the conceptual knowledge that the student has.

Anastasiou & Alves [8] also suggest the conceptual maps as a strategy of teaching in the classroom. The justification is based on the main thinking operations which allow the interpretation, classification, critics and the organization of conceptual data in a hierarchical manner.

The conceptual maps dimension can be contextualized by classification where dimensional maps tend to present a linear vertical organization giving a broad view of the concepts of a subject. The two dimensional maps, on the contrary, use the vertical and also the horizontality perspective and, therefore, allow a more complete representation of the relations among the concepts of a subject or about a specific aspect.

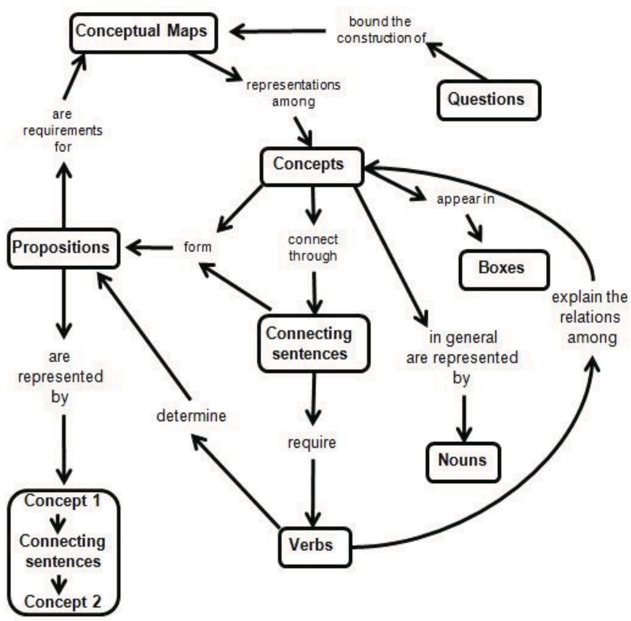

Figure 2. Schematic representation of the relvant aspects of a conceptual map

Source: the authors of this research

In this study, the conceptual maps were used to identify the conceptual domain of the students about the equations and mathematical functions which allowed the evaluation of the level of knowledge of both mathematical concepts. The results showed a simple conceptual map where each student built his own Initial Conceptual Map having as the main point the equation and function from the mathematical point of view. With this, it can be said that the students have different difficulties as to understand the quantities directly and inversely proportional, the meaning of an independent variable, among others.

C. *Gowin's Epistemology*

The scientific investigation process according to author [2] is the construction of meaning structures from basic elements named as events, objects, facts and concepts. The initial idea is from the observation of a specific event or object which occur in a natural way or is even created by the observer, the procedure of research relates specific relations among the observations of the event done, its consequences derived from the studies of the event, the assertions made by the consequences and the concepts, by the definitions used to interpret, analyze in order to get to the explanation of the event or object.

Concepts are defined according to authors [2] and [3] as signs or symbols that describe regularities in events we use to do in an action as thinking, researching, learning, aiming at finding an answer to the observable events. Conceptual systems are sets of definitions logically connected which allow default reasoning as we relate concepts. For author [3] this fact can signify that the event itself occurs naturally or is caused by the observer or the researcher and it can also be understood as the event registration, or yet, the facts are verbal or mathematical assertions, based on the events registrations.

The research process according to Gowin's perspective is a way to generate signification structures connecting concepts, events and facts. Figure 3 shows this connection in a "v" shape matching events in the bottom to concepts and facts on the sides.

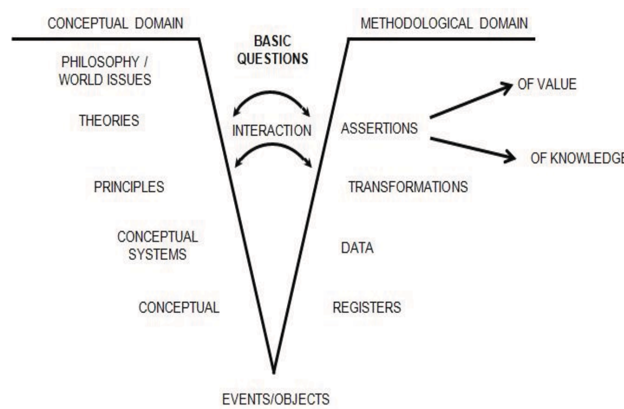

Figure 3. Gowin's epistemology of the 'v'.

Source: Moreira & Buchweitz [10]

The left side refers to concepts and conceptual systems called as conceptual domain of the investigation process where the effective concepts and the conceptual concepts used in the research are situated and generate principles and laws, which also create theories. Value systems, world views and philosophies are related to the theories. In the "v" bottom are the events that happen naturally or that are caused by the researcher in order to obtain registrations through which the phenomena can be studied. Sometimes the phenomenon observed is studied through objects and in this case it can be said that the event is the object itself.

In the case of the knowledge observed in this research that involves mathematics and physics chemistry, the bottom of the 'v' is made of concepts of equations and functions. On the conceptual domain side we have the independent and dependent variables, the quantities directly and inversely proportional, linear and rational function, graphics representation and operations about the set of real numbers. On the other side, on the methodological domain, we have the gas transformations, behavior of an ideal gas, graphical representation with the variables involved in the gas transformation, physics and chemistry analysis and interpretation. The interaction process was realized with the use of the graphical simulator.

The pre-test was constructed in two steps. In a first moment, five theoretical questions were developed about the signified of the content described above, as it can be seen below:

1- What is a mathematical equation?
2- What do you understand as a mathematical function?
3- What is the difference between a function and an equation? Explain it with your own words.
4- Give the definition or explain the meaning of an independent and of a dependent variable.
5- What is the meaning and the purpose of a graphic in mathematics?

In the second step of the pre-test ten questions were created to be answered in an analytical way and eight of them were based on operations involving real numbers and two were described as problems with quantities directly and inversely proportional.

The questions above were answered by twenty students. The result of the first stage showed that most of the students did not answer the five theoretical questions. Two possibilities were raised as possible justifications for this situation:

1º) The students do not understand the concepts;
2º) The students can not express their ideas.

In the second stage of the pre-test ten questions were created to be answered in an analytical way and eight of them were based on operations involving real numbers and two were described as problems with quantities directly and inversely proportional.

Not all the questions in this part were solved by the students. The average of right questions was near 58% (fifty-eight percent) where a higher number was expected.

Through a detailed analysis of the mistakes done, the following were highlighted:

1º) $4/0 = 0$
2º) $2^{-1} = -2$
3º) $3^{1/2}$ = no answer
4º) $x^2 = 36 \Rightarrow x = 6$ (only)
5º) $x^3 = 27 \Rightarrow x = 9$
6º) $\log_2 16 = x \Rightarrow x$ = no answer

In relation to the two problems, part of the students got to the right answer identifying the quantity directly and inversely proportional, but the other part did not get the answer or did not answer the problems. In this last case, among the students that did not do the problems right, most of them chose not to answer the questions.

An initial justification concerning the mistakes of the students is due to the difficulties in understanding or the domain the mathematical conceptualization during his student life, regardless as a high school student or as a graduation one. Another possibility is that the students find difficulties in subjects like calculation because at most cases they need to take the subject more than once. It also reflects in the low number of students enable to take the discipline of Physics Chemistry I.

Relating it to the meaningful learning theory it can be perceived that the students are owners of some subsumers related to some subjects, as an example, operations with numbers. For those who do not have these, they are exposed to new problems with a different focus to avoid the repetition of activities and to put away the possibility of memorization.

Figure 4. Screen from the graphical simulator used to show an isobarican transformation

III. PRE TEST RESULTS

The pre-test with students of two groups of the Physics Chemistry I subject was realized in the beginning of the second term of 2008 and 2009 to verify the existence of subsumers related to the mathematical functions and equations. It was consisted of expository questions and activities to be solved about the math contents needed to the understanding of the ideal gas Law. The results showed that most of the students have difficulties to apply, analyze and interpret the mathematical concepts used in problems applied in the subject in question. It was quite evident that most of them (between 40% and 50%) do not present the subsumers related to the equations and functions for the Ideal Gas Equation.

Based on the initial results, in the second term of 2008 a decision to work in an interdisciplinary way was taken. For that some monitoring activities of the practical classes in the subject were realized by a mathematics professor. During the laboratories classes the Mathematics and Chemistry professors participated in the process realizing the connections between the two areas in a way to highlight the applicability of the math concepts in chemistry.

Interdisciplinary for author [7] is characterized by a group of disciplines, or areas of related knowledge, which aims at achieving the objective established by one or more coordinators of the process. In this specific case of the ideal gas law the common element is the equation which represents the variables involved in the process as a transformation that occurs in an ideal gas.

The results obtained up to the present moment reinforce the assumptions of the meaningful learning theory. Preliminary surveys of the pre-test showed the identification of the specific subsumers which were worked with the development and application of the Simulator causing the development and post preparation of new concepts insertion for the student.

The mathematical conceptualization needed as a requirement for the Physics Chemistry I Subject more specifically related to the ideal gas Law is potentiated with the use of the simulator. In the graphic representation and in the table which related the variables, the student perceives the concepts of the quantities directly and inversely proportional besides checking the difference between independent and dependent variables. Another relevant aspect would be the representation of specific points delimited by values inserted in the Simulator to express a linear function and a rational function.

The simulator allows the comparison between the first and the following representation demanding the reasoning of the student to identify the position of the following graphic as well as of the third and last graphic.

The use of the simulator also helped the student in the improvement of his initial conceptual map due to concepts seen in the mathematics subjects, as the calculations. New relations among the contents were represented and checked creating a new and more elaborated conceptual map. This shows that the students developed the specific subsumers proving domain over the mathematical concepts in their new cognitive structure. In this case, they are capable of receiving new definitions and information according to author [4].

The mathematical background allows the chemistry professor to relate, with the technical conceptualization seen in the subject, the real gases that behave close to reality in the value numerical ranges of the variables involved in the process.

IV. CONCLUSIONS

The activity of identifying the knowledge acquired and of confronting it with its applicability is not an easy task as it demands the group commitment for those who really search the complete domain of the concept presented by the professor. This raises the critical sense in the students and contributes for their future formation.

In the monitoring process of the learning development done in the classroom it was identified that the students have the capacity to recognize and define problems but they have difficulties in finding the solutions and in realizing the analysis as also the interpretation.

The process of use of the simulator was done by the reception learning according to author [6]. It is expected that the simulator can really contribute with the concepts understandings as it allows the realization of comparisons inside the transformation through three kinds of functions represented in the same space where that variation of the number of mols allows a more effective mathematical analysis. Besides, the independent variables selection permits the same inference and also of the variable that assumes a constant value throughout the process.

The initial and final use of conceptual maps, the last to be developed, can show the evolution of the students in the comprehension of the equations and functions concepts as there is a tendency of specifying and of reorganizing the existing relations in the cognitive structure described before, as well as of the increase in the number of related concepts.

It is also perceived that interdisciplinarity can contribute in a way to organize the thinking and to complement the knowledge acquired improving the general view of the concept taught. So we suggest its applicability inside the Physics Chemistry I Subject as well as in other disciplines that allow the association between mathematics and chemistry.

The simulator use will certainly bring other contributions to the research as well as the increase in the new results found up to this moment. It is intended to improve the interface and the functions of it in a way to create new situations that evolve the study of the real gas and also to follow new groups of Physics Chemistry I groups to obtain a comparison between the groups followed now.

It is intended to do future research to supply some aspects that in this research could not be completed and for that a new research is suggested with differentiated instruments in relation to the ones used up to the present moment.

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Session 02G Area 1: Learning Objects reusability and digital repositories

Authoring Environment for E-learning Production Based on Independent XML Formats

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Technical congress proceedings as a reusable digital objects educational source

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Virtual analog and digital communications laboratory: LAVICAD

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Open educational resources (OER) inspire teachers and motivate students

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Authoring Environment for E-learning Production Based on Independent XML Formats

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Abstract— **E-learning content production has faced the problem of making content independent from authoring applications and delivery platforms. Both aspects are very relevant to the need of keeping learning institutions as much independent as possible from software vendors. Content independence and interoperability is also required to easily share and move e-learning repositories. We propose a user friendly authoring environment based on the independent, open and XML compliant product Docbook; its simple, flexible and well structured markup make it easy to interoperate with other XML languages, particularly those related to e-learning. We are particularly interested in IMS Content Packaging and IMS QTI because they allow importing learning material into our Sakai based learning management system named PoliformaT. Docbook has also a powerful and fully customizable set of XSLT styles sheets that allow high quality web and paper delivery. The user front end is built on the commercial XML editor from XMLmind XXE. The major part of the environment is portable to other XML editors because it relies exclusively on Docbook components. At the moment the proposal presented is much more flexible, usable and productive than the available alternatives.**

E-learning; interoperable formats; XML; IMS; Docbook

I. INTRODUCTION

After being established as a mature technology e-learning has faced the problem of content management in such a way that content be platform and vendor independent. XML originated on the web as a set of standards that provide open and independent data representation and processing, has become the more convenient platform to define interoperable content representation. In spite that these efforts have been more oriented to content packaging (i.e. SCORM and IMS Content Packaging), nowadays there are XML compliant languages that cover the whole range of content types (text, graphics, multimedia, etc). In this way interoperability and standard data processing can be applied to the whole content hierarchy, from individual content items to a whole subject, course or set of courses. In this work we present a learning content authoring environment based on the XML compliant and open product Docbook [1]. The main interesting features of Docbook are its well structured and format independent definition, its total independence from particular software products and vendors, and its complete set of mature and well tested web and paper format generation tools. The simple and well structured Docbook markup simplifies its interoperability with other XML compliant standards, particularly those oriented to import and export e-learning content in learning management systems (LMS) [2].

Docbook has been the framework of choice in other e-learning related works like [3][4][5][6][7]. In [7] we developed our first Docbook customization (TeachdB) aimed to provide content reuse and one-source-multiple-format delivery. In this work we present an extension of this customization oriented to interoperate with IMS Global Consortium Standards [2], particularly IMS Content Packaging (CP) [8] and IMP Question and Test Interoperability (QTI) [9]. The whole publishing process is schematically depicted in figure 1.

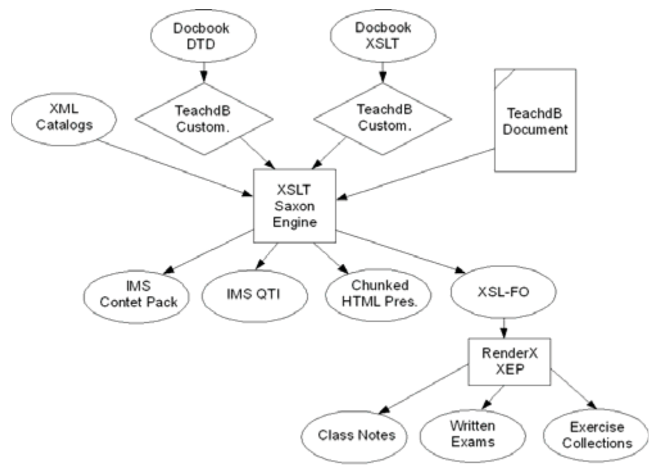

Figure 1. E-learning publishing process based on Docbook.

The ability to easily produce IMS CP and QTI is a key feature for us because our university has based its e-learning support on a Sakai [10] customization named PoliformaT [11] and Sakai uses these two IMS standards to import and export content modules and assessments, respectively. Then our main contribution is the development of a concrete friendly e-learning production tool based on open, independent and XML compliant standards and fitted to Sakai as target LMS. The approach can be applied to other environments like SCORM formats and Moodle LMS [12].

The content of the paper is organized as described next. In section 2 we briefly describe IMS CP and QTI standards. Section 3 is dedicated to summarize our Docbook customization [10] intended to fulfill our requirements. Section 4 contains the main issues involved in the implementation of IMS CP and QTI generation from our Docbook customization. Section 5 describes how authors have to use the environment. It also includes a description of real production examples and some figures about the impact that it had in our teaching experience. Section 6 is devoted to compare our proposal to other available alternatives. Finally some conclusions and future work directions are considered.

II. IMS CP AND QTI STANDARDS

IMS Global Learning Consortium began at 1997 and since then it has published about 20 standards dealing with interoperability for learning systems and learning content and the enterprise integration of these capabilities [2]. In the next two sections we briefly describe the two IMS standards that are relevant for us: IMS Content Packaging and IMS Question and Test Interoperability; both are XML compliant.

A. IMS Content Packaging

As stated in the standard "the IMS Content Packaging provides the functionality to describe and package learning materials, such as an individual course or a collection of courses, into interoperable, distributable packages" [8]; its latest version is 1.1.4.

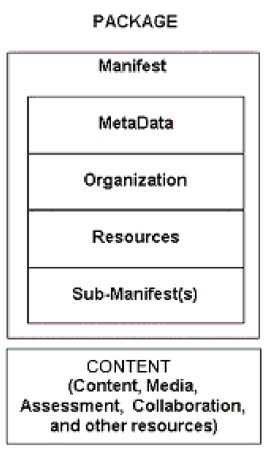

Figure 2. Content Package structure.

As shown in figure 2 a Content Package has two parts: a manifest and a content pool. The manifest corresponds to an XML file, commonly named *imsmanifest.xml*, with a root element <manifest> with the following child elements:

- <metada> is an optional element that describes the package according to IEEE 1484.12.1-2002 standard for Learning Objects Metadata. Other metadata can be included by their corresponding namespace.
- <organizations> is a required element with zero or more <organization> children that describe the structure of content resources.
- <organization> includes a hierarchical composition of <item> elements pointing to content resources by means of unique ids.
- <resources> is a required element that includes the references to all the content resources included in the package by means of a unique id and a sequence of one or more <file> children.
- <manifest> is an optional element that specifies zero or more sub-manifests.

The manifest, schemas and resource files are packed into a compressed file, typically using ZIP format. The manifest and the schemas are located at the root and resources are organized into subfolders.

B. IMS Question and Test Interoperability

IMS Question and Test Interoperability is defined by the standard as "(it) describes a basic structure for the representation of question (item) and test (assessment) data and their corresponding results reports" [9]. The latest version of IMS QTI is 2.1 but at present PoliformaT only supports version 1.2, then this will be our target version.

There are two aspects covered by the standards ASI and Results Reporting, both are totally independent. ASI stands for "Assessment, Section, Item" and it is the component relevant to us because it deals with assessment authoring.

An IMS QTI ASI compliant document is an XML document validated against the schema *ims_qtiasiv1p2.xsd*. Our LMS uses IMS QTI ASI as the format to import and export exams and, among all the compliant structures, it only accepts the following one:

- A root element <questestinterop> with one <assessment> child. In fact only one <assessment> element can be included in an IMS QTI compliant document.
- The <assessment> element includes one <section> child.
- The <section> element includes a sequence of <item> elements. Every item implements an assessment question.
- An <item> element is compounded by three elements:
    - <itemmetadata> describes question features like the type of question.
    - <presentation> includes presentation content like enunciate and response options.
    - <resprocessing> includes the description about the response alternatives (correctness, score, etc).

III. DOCBOOK AUTHORING ENVIRONMENT

The basic Docbook 4 tools are the DTD files and the XSLT stylesheets that produce web and print formats. Both of them are open source and can be obtained from the Docbook site [1].

These basic tools have to be complemented with an authoring frontend and some customizations in order to be productive and fulfill particular application requirements. Either DTD and stylesheets are fully customizable at several levels of complexity [13][14], usually simple customizations will suffice.

In the next two sections we briefly describe our Docbook markup customization and the tools that we have selected to produce and manage documents.

A. TeachdB markup

We have minimized markup customization in order to maintain the maximum compatibility level with Docbook. We have named our customization TeachdB [7].

Our learning/teaching documents are subject themes, lab guides and exams. Subject themes include theory and solved and unsolved exercises. Lab guides include theory briefing, lab activities and exercises. Exams are built reusing exercises from subject themes and lab guides. Exam questions can be open or test type, at the moment we only support multiple choice one answer test questions.

The delivery formats were initially chunked HTML briefings, to be used as class presentations, and PDF to deliver class notes and exercise collections to students in paper format. Lab guides and exams are delivered to students as PDF. The preference of paper format was because we began our Docbook working before PoliformaT started. Even after PoliformaT paper format is still widely used.

From the technical point of view subject themes and lab guide documents use <article> as root element. To distinguish one type of document to another we have made the next Docbook customization:

- *role* attribute of element <article> is restricted to “class” and “lab” values.

An important issue in our customization is exercise management and then the main markup customization part is related to exercises. We implement exercises using <qandaentry> elements. Docbook organizes <qandaentry> elements inside <qandadiv> elements and <qandadiv> elements are grouped into <qandaset> elements. We classify exercises into delivered in class notes, stored in repository and candidates for exam. This is implemented by means of the following customization:

- *role* attribute of element <qandadiv> is restricted to “class”, “repo” and “reserved”.

In Docbook a <qandaentry> element has one <question> child and cero, one or more <answer> children. We have customized <qandaentry> elements in order to be able to:

- Mark an exercise as solved (show the solution) or unsolved (hide the solution).
- Know their last use type and date.
- Implement multiple choice one answer test questions.
- Select a solution pattern or a complete solution depending on the type of document delivered (i.e. exam or exam solution).

The customization consists of:

- *role* attribute of <qandaentry> element is restricted to “example” and “exercise” values.
- Two new attributes *lastusetype* and *lastusedate* are added to <qandaentry>.
- A new element <options> is added to <question> element in order to implement multiple choice questions.
- A new attribute *type* is added to <answer> element, with available values ‘response’ and ‘solution’.

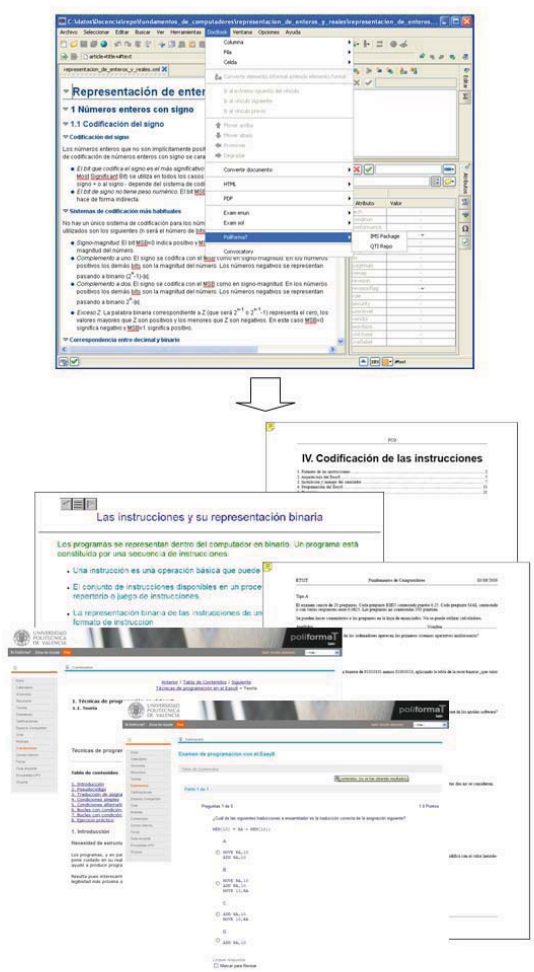

Figure 3. One content source multiple delivery formats.

Written exams are produced using XInclude in order to avoid content duplication and allow content reuse. In this way exams are built by pointing exercises located in subject themes or lab guides. This mechanism has improved noticeably the exams quality in such a way that exams errors are much less probable. Exam document have their own new markup tree described in [7].

The extension to deliver IMS CP and QTI has not imposed any additional markup customization if we limit content to text and still images. However these new formats are able to include interactive elements, like Java applets and multimedia clips, into both module sections and QTI items. So we are considering a customization of Docbook <audioobject> and <videoobject> elements, and the addition of the element <appletobject> at the same level as the former ones. At the moment we simple use standard Docbook <ulink> elements to include these types of materials.

We also plan to extend our QTI item support to fill-in the blanks that will require extending our <qandentry> customization.

Another candidate for customization is metadata, at the moment we do not include metadata inside IMS CP or QTI apart from the general metadata included in PoliformaT templates. Hierarchical elements in Docbook include info children like <articleinfo>, <sectioninfo> and <blockinfo> that can be customized as metadata containers [3].

B. Authoring tools

In order to be productive a user friendly editor has to be selected. XML editors tend to be difficult to use by non experts and this has been an important handicap to XML. Nowadays the situation has changed and there are at least two products that offer a comfortable interface to authors:

- XMLMind XML Editor (XXE) [16].
- oXygen XML Author [17].

XXE was probably the first XML editor oriented from the beginning to authors. We have followed its development and its evolution has been impressive and it certainly offers an easy to use and productive interface. At present XXE is our choice. oXygen has been mainly oriented to XML programmers and recently the Author version has been released. It is an alternative to keep in mind. Both XXE and oXygen XML Author are commercial products but very affordable licenses are available for academic use.

Our Docbook customization can be easily ported to both editors because it mainly deals with Docbook itself. Our first attempt has been to embed it inside XXE.

IV. IMS CP AND QTI PRODUCTION TOOL

After becoming aware of PoliformaT use of IMS CP and QTI formats for importing and exporting courses and assessments we began to extend our production environment [7] to automatically produce these formats from our pool of TeachdB documents. Basically it requires the implementation of some XSLT stylesheets that reuse Docbook XSLT for HTML generation and some simple console scripts. The scripts are platform/tool dependent but XSLT code is portable.

A. IMS CP Generation

Every subject inside PoliformaT has a Content site where content is organized as modules that contain one or more sections. Every section can be a single or chunked HTML page. The content inside Content site can be exported or imported as a whole or module by module using IMS CP.

We use the Content section of our subjects in PoliformaT as a complementary way to publish theory and problem collections. This material is also published as PDF in another subject site named Resources. The added value of HTML is that it allows enriching our learning documents with interactive elements like Java applets, multimedia clips and web links.

We import the subject content in PoliformaT by modules, in such a way that every module corresponds to a subject theme.

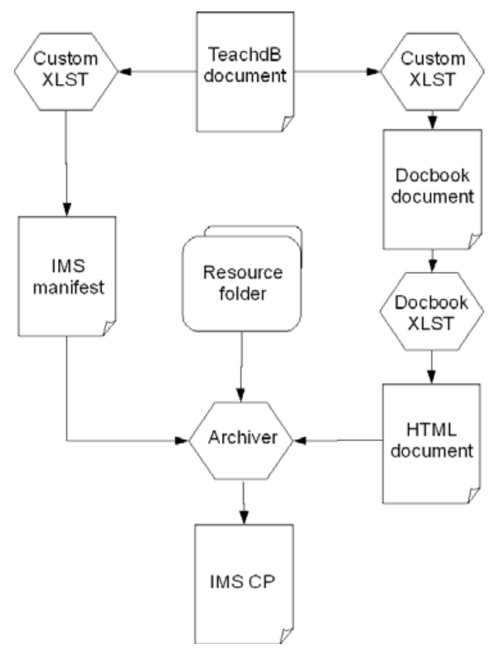

Figure 4. IMS CP generation procedure.

The exercises customization performed in TeachdB allows marking exercises to be solved, unsolved or reserved and then this characterization permits to filter what set of exercises will be published in the Content site or in the Exams site (as we will shown in the next section) and what exercises are reserved to produce written exams.

In order to get from a TeachdB subject theme file the theory and the solved exercises and to pack them into an IMS CP to be imported in PoliformaT we perform the procedure described in figure 4.

We have implemented two XSLT style sheets. One of them produces an intermediate Docbook document from TeachdB in order to use the standard Docbook XLST, properly customized, to produce a single HTML page. The other XLST style sheet produces the manifest document for the content package.

Finally an archiver packs the manifest, the HTML page and the local resources into a ZIP file that will be delivered to PoliformaT.

B. IMS QTI genaration

The implementation of QTI import/export procedure in Sakai 2.4, corresponding to PoliformaT at present time, is rather rudimentary. The automatic importation procedure only accepts a QTI valid file, with some additional restrictions, and any other auxiliary material (figures, graphics, applets, etc) should be uploaded manually to a public folder inside PoliformaT. Considering this situation our QTI assessment generation procedures is depicted in figure 5.

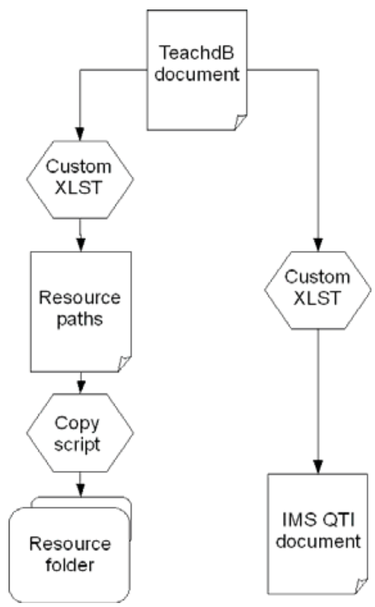

Figure 5. IMS QTI generation procedure.

The custom XSLT that produces the IMS QTI document takes from the TeachdB input file <qandaentry> elements that include an <options> children and that are included inside <qandadiv> elements with *role* attribute set to “class”. The Docbook hierarchical elements are translated to QTI and content markup is converted into HTML by reusing templates from Docbook XSLT. This is implemented by importing the main Docbook HTML style sheet into our QTI producer style sheet.

The other XLST style sheet produces a resource description text file, containing path location for resources (i.e. still images), that is generated by parsing the source TeachdB file. This description file is later read by a copy script that makes a copy on a resource folder of every resource used by the <qandaentry> elements included in the IMS QTI file.

The QTI file is imported in PoliformaT by the import procedure available in the subject Exams section and the resource folder is uploaded by WebDAV to a previously stated public folder inside PoliformaT.

C. XXE Customization

We have implemented inside XXE editor the procedures describe in the two previous sections. XXE has very powerful customization capabilities that allow adapting it to any XML compliant markup offering a friendly editing interface based on CSS [19]. In the professional edition the application menu can be customized with new entries that correspond to XML code able to call external XSLT style sheets and a set of command implemented inside the editor [20].

The customization is performed by including inside a customization folder the DTD for TeachdB, the CSS style sheet to get a friendly editing interface, a set of document templates, the XSLT style sheets that perform format generation and the customization file that integrates all the previous elements. This configuration file is XML compliant according to a schema created by XMLmind specifically to configure XXE. XXE itself has an addon that allows editing configuration file.

The TeachdB customization for XXE Professional Edition, in the state as it is at the time of this writing, can be downloaded from [21]. Figure 6 shows how XXE looks like when the customization is active.

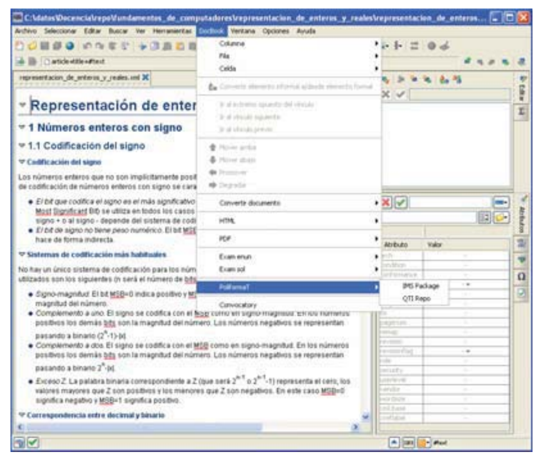

Figure 6. XXE with customized format generation menu entries.

V. ENVIRONMENT USE AND LEARNING IMPACT

We have been using the proposed e-learning production environment since course 2005-06. We have authored three subjects with it, one of them was created just reusing content from the other two by means of XInclude.

A. Environment use

The procedure to produce a subject is to decompose it into modules or themes. Every module is created using the <article> template of TeachdB inside XXE. The content of a module is organized into sections, commonly up to a three level deep section tree. Inside a section the content is organized into <simplesect> elements that are terminal sections in the document tree. A <simplesect> can be seen as a slide and contains an optional title and a sequence of content elements like paragraphs, items lists, tables, images, etc.

Exercises are included inside a <sect> or <simplesect> element using the <qandaset> container. The organization of exercises is explained previously in section III.A. Exercises are authored filling the <question> element with content elements (paragraphs, item lists, tables, images, etc) that define the exercise enunciate. If the exercise is a test question then the last element in <question> has to be one <options> element that defines the multiple choices for the test question. The first item of the <options> element has to be the true answer. When test exercises are imported in PoliformaT they are randomly reordered when students start the exam. After the <question> element we can optionally include one <answer> element with a response template (incomplete tables or images, clues for the solution, etc) and one <answer> element with the complete solution. The attribute *type* of <answer> element distinguishes both cases as we have described in section III.A.

To produce a module to be imported in PoliformaT we select Docbook menu, PoliformaT and IMS Package (figure 6). This produces an imscp.zip that is imported in the Content section of the subject in PoliformaT without any further manual operation.

A similar procedure is followed to produce a QTI exam. We do Docbook, PolformaT and QTI Repo (figure 6) then a qti.xml file is generated that is imported in the subject Exams section in PoliformaT.

A video demo is available at [27] showing the previously describe procedures.

B. *Learning impact figures*

The switch from using presentation slides and exercises collections provided only in PDF format, into our new approach has had a noticeable impact in the learning process. We thing that there are three main reasons for this improvement, first the new IMS Content Package format allows including more active elements like videos and applets.

Then we are able to make use of the new streaming platform PoliTube started in 2007 by our university to deliver learning videos. They can be included in modules by just a PoliTube link or embedding the video using the <embed> HTML element. Another reason is related to QTI as a more dynamic way of publishing exercises, together with the capability of publishing exercises with or without solutions from a single content source. Finally, the procedure to produce written exams automatically by reusing exercises already published and tested has improved quite noticeably the quality of written exams and this is greatly appreciated by students.

Year	p1	p2	np	abs
2005-2006	71	24	89	49
2006-2007	63	17	76	36
2007-2008	61	46	55	28
2008-2009	85	20	39	33

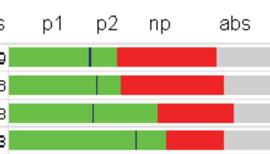

Figure 7. Learning results for a sample subject.

Some figures that measure this improvement in the learning process are shown in figure 7 and in figure 8.

Figure 7 shows how the percentage of passing students has got bigger and bigger and that the contrary stands for the percentage of non passing students. The percentage of absent students is more o less the same.

Figure 8 shows that since the proposed authoring environment is in use (2005) there is a jump of 1.5 points in the mean lecturer opinion pool score (upper line over lower line).

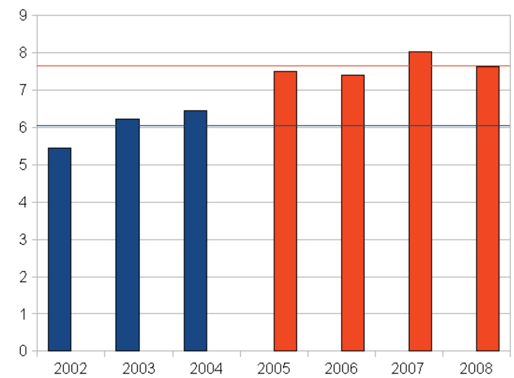

Figure 8. Lecturer opinion pools scores.

VI. COMPARING TO OTHER APPROACHES

The technique that we have presented has to be compared with the following available alternatives:

- Editors embedded in Sakai 2.4.
- Common word processors.
- Specific IMS authoring tools
- E-learning editor eXe.

Sakai 2.4 includes edition tools to produce content modules and assessments [10]. These tools can not be used outside the platform and then their use requires Internet connection which nowadays can still be an inconvenient. The editors are implemented as Java applets and then they suffer from high startup time and lack of functionality compared to common editor applications. Sakai editors neither support good quality printing format.

The previously mentioned shortcomings are not present in commonly used word processors like MS Word and OpenOffice Writer. These editors have another inconvenient, their XML formats are not structured (flat) and very complex, particularly they include a lot of formatting information in their markup [18]. This makes very difficult to implement automatic tools to translate documents to IMS formats, particularly QTI. Our Information Systems Support Department has developed a macro to produce QTI from MS Word documents but it has many restrictions that forces authors to pay a lot of attention in the editing process and limits the type of content in the QTI documents produced. The Open University [22] has also developed an MS Word customization that allows using a custom markup language inside Word in order to facilitate the generation of IMS formats [23]. This markup can be seen as a quite limited Docbook subset. Furthermore, XSLT has to be built from scratch loosing the capability of reusing the powerful and very well tested Docbook XSLT style sheets.

For the present work the more relevant IMS formats specific tools are RELOAD [24] as Content Packaging tool and AQuRate [25] as QTI editor. RELOAD is just an IMS CP editor which means that it is not a content item editor. Content items should be created with other tools and RELOAD allows integrating them into an editable IMS CP.

AQuRate produces QTI 2.1 assessments with a friendly interface and it supports the set of items that we are interested on. However, it lacks from good quality printing generation and we still depend on paper format. AQuRate neither includes at the moment a friendly table editor. Another shortcoming for us is that only the assessment part or our learning content can be produce with AQuRate, then theory content and exercises have to be kept appart. QTI produced with AQuRate generates errors when importing it into PoliformaT, then an additional adaptive transformation must be applied.

Finally eXe editor is an open source project (exelearning.org) that intends to offer a free e-learning oriented content editor that enforces compliance with IMS CP and QTI. The main problem with this tool is that it is not easily customizable, for example it is difficult to get good printing format. The native format is XHTML that is good for the web but really inferior to Docbook in relation to automatic document processing and management.

Our framework built on Docbook has all the benefits of the alternatives mentioned and it avoids their drawbacks. The XML editors we have mentioned, XXE and oXygen Author, are Java applications that are installed locally and do not have functionality restrictions. Docbook markup is well structured and simple, facilitating XML conversion. Furthermore, Dosbook XSLT style sheets allow full control on the production of screen format (HTML) and paper format (PDF). We certainly appreciate this feature and in fact this was one of the main reasons for our initial choice of Docbook. Finally our authoring environment allows producing theory and exercises together which is quite convenient in order to have a consistent content view. When we generate IMS CP and QTI from our customization they match the patter that PoliformaT imports without errors.

VII. Conclusions and Future Work

After having used Docbook extensively as our framework for developing and deploying learning/teaching materials [7][15], we have presented in this work an extension for Docbook interoperation with IMS learning formats in order to easily produce e-learning content that can be automatically imported in our Sakai based LMS platform PoliformaT. Our work is being considered by our Information Systems Department and it received a good appreciation at the September 2008 IMS Quaterly Meeting [26]. A video demonstration of how our tool produces IMS learning formats inside XXE and how these formats are imported into PoliformaT can be seen at [27]. This extension of format delivery from our learning content pool has been fairly easy to implement and it has proven to be very effective, consolidating Docbook as a solid e-learning production tool alternative.

As IMS formats management continue to improve in future Sakai releases we will keep track adapting our environment to the new features. Particularly it is foreseen that Sakai will support IMS Common Cartridge that mixes IMS CP, QTI and other IMS standards into a common standard for e-learning content delivery and interchange.

Docbook is also evolving to version 5, nowadays version 5 is not mature enough to replace version 4 in production but it is worthwhile to consider migration at the right time. Docbook 5 is a complete rewrite of Docbook based on RELAX NG schema validation and includes new features like using XLink as the single linking mechanism, namespaces that allow embedding into Docbook documents other XML makups like MathML and SVG, and easier customization. Porting Docbook 4 documents to Docbook 5 requires little changes that can be automatically performed by simple XLST code.

There are other markup languages that share some of Docbook nice features like DITA. But at the moment we have not found any reason to leave Docbook. If this has to be done in the future the simplicity and good structure of these XML markups make their interoperation easy.

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Technical congress proceedings as a reusable digital objects educational source

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Abstract — **The use of technical articles in scientific and academic scopes is a well-known way to extend new creations and researching jobs throughout the world, mainly as a communication medium of knowledge among educational professionals. Nowadays, with no doubt, the Internet, is the usual way to spread any kind of documentation. Authors send the contents of their publications, based on a typical scheme composed by an abstract for a first understanding of the paper, some names, references and a further content development, using textual descriptions and graphical support elements. These parts of the document are conformed in a unique data unit. However, even the article taking part of the congress edition, the access way to it, is made through the digital media given by the congress. So, only if some congress query media are developed, it's successly possible to access to a certain article information.**

The experience shown in the content of this paper gives a solution to this access problem and bases its development on the information treatment of a congress as digital learning objects. By this way, a technical paper is treated as an information unit which is composed by a data background, essentially the metadata, which are recovered and isolated in every individual documentation.

Once a digital object and its metadata are disposed, congress edition conforms a structured data block, accessible not only in the congress scope but outside it. The use of metadata standards, as IEEE-LOM, let to information being built in digital platforms and repositories to be treated as congress information, as an individual article and even, some of its parts, as reusable digital objects

Keywords- ***learning object; reusable content; metadata; technical article***

I. Introduction

This paper introduces the procedures based on the treatment, classification and organization of the information extracted from technical articles generated in several congresses in the field of Electronics [6]. The project scope has as a primal objective, the extraction of a set of metadata [14], which define every publication in the context of a congress issue, to obtain the information related to the technical and teaching information from the publication content [5], in order to be treated as a digital object by means of its metadata.

The metadata obtained will lead to a set of references associated to every article, whose implementation let the converted digital objects to be treated as reusable learning objects [9]. Subsequently, a data-metadata set will be configured in a files structure, which permits the implementation of some actions as the creation of an homogeneous web site to access them, the dissemination of the structured contents on the Internet through repositories and digital contents platforms [16], and as a final work, to analyze the contents of the information in the congresses to study the resultant information in a tendency studies and organizations relations in Electronics and Teaching fields. To carry out the project actions, the TAEE conference (in Spanish, Applied Technologies for the Electronics Teaching) has been selected because of its increasing track as well as the variety of themes in Electronics scope.

II. The treatment of digital objects

Through the celebration of TAEE conferences since 1994 to 2008, 964 documents have been published. All of them are susceptible to be converted in learning digital objects. It has been necessary to apply individualization actions in every publication in order to maintain a homogeneous appearance, given the different formats of creation and publication, as well as classification methodology to keep the papers in a common context.

Every document has been converted in electronic format and has been deeply analyzed to extract from it every component to be useful in a reusable learning context. These actions have taken in place 4441 additional component digital objects. All of them conform an heterogeneous set, i.e., their types as MIME digital objects has been classified in texts, graphics, data spreadsheets, web pages, photografies, etc. [12]

In a parallel way to the formation of every digital object, main digital objects and component digital objects, it has been performed a file structure to keep them in. The structure is based in the biannual organizations of TAEE meetings. To be placed in the structure, every learning object has been named by means of an ad-hoc unified code system to let every digital object be associated with every metadata file in an homonym way. This code system has been based in a hierarchical system as Decimal System (DS) [17] but modifying the kind of characters given to every name in order to recognize the object belonging to a determined congress, session and order of paper. It can be said that the names codification also offers the first object metadata by itself. When finishing this stage, a files structure is disposed, inside which every digital object and every metadata definition file are placed. [13]

III. DIGITAL OBJECTS METADATA EXTRACTION

To implement the digital objects metadata extraction process it has been required the achievement of a metadata structure appropriated to maintain each of the relevant datum in every article. To do this, two different aspects have been taken into account: the object belonging to a congress context and the property of reusability as learning objects. By that, the IEEE-LOM (*Institute of Electrical and Electronics Engineers – Learning Object Metadata*) metadata standard [1] has been studied to be modified in order to use it in TAEE context. The metadata structure obtained has some similar features, given the use of LOM as a metadata system focused to learning contexts. Other standard are available to perform this action, as Dublin Core (DC) [2], but authors have considered that the standard offers a partial solution to TAEE needs, given it's a common metadata system used in library funds registration, but not having enough focus to educational or learning items. However, if there's a reduced and specific metadata amount per item, both metadata system (LOM and DC) are compatible [4] between them and TAEE system, but this compatibility is compromised if the digital object has to be defined by a greater amount of elements.

In LOM, metadata are grouped in nine main blocks to maintain a hierarchical disposition: *General, Lifecycle, Meta-metadata, Technical, Educational, Rights, Relation, Annotation, Classification.* Each of them defines respectively a metadata clustering in relation to the digital object definition scope. To extend the definition of every metadata group, some qualifiers are additioned to them to offer a complete structured composed by 64 metadata. In table 1, some explanations of LOM main groups are given.

In the case of the TAEE learning object, a new organization in metadata grouping has been made, as shown in Figure 1, in a suitable way according to digital objects information in the conference context.

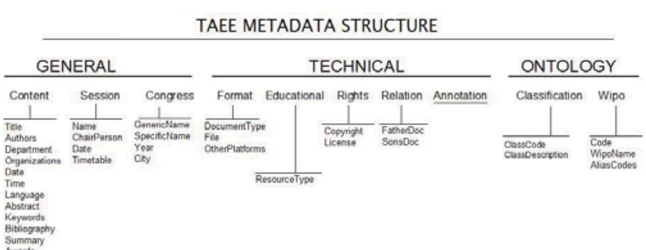

Figure 1. TAEE metadata structure

The metadata structure, therefore, offers in a first instance a division in three main blocks: *General, Technical* and *Ontology*. The first one, *General*, attends to those metadata that identify the digital object in global conference features, such as the object contents, the session and the event, establishing the nature of every document.

In the *Content* subgroup, the involved metadata are defined as "*Title*", "*Authors*", "*Departament*"and "*Organization*" to define the denomination and responsible organization; in addition, "*Date*" and "*Time*" has been created to define the exposure features in the session and congress limitations. The metadata "*Language*" let to know the language used in the paper, using the standard ISO 639:1998. "*Abstract*" and "*Keywords*" are available in the way the original texts have been written and with the information they keep it's possible to approach to the content of the full document. Other metadata as "*bibliography*", "*summary*" and "*awards*" complete the block.

The second metadata block "*Technical"* provides technical matters in relation to the original format of the document, its denomination and definition as a digital file (as done in the codification process), the kind of learning object, the owner's licenses and rights and the relation between main objects and its dependent components.

The last block "*Ontology*" is mainly based in a TAEE-specific-purpose subject structure as an electronics classification method, TAEE ontology, and it has been implemented in "*Classification*" metadata. TAEE Ontology has been created to match every subject to one or more classification families, by means of which a thematic definition can be made in the areas of electronics and teaching. In addition, it has been incorporated WIPO codes as a supplementary way of ontology, using the information given by WIPO (World Industrial Property Organization) which uses it to classify every granted patent or industrial model.

TABLE I. MAIN CATEGORIES IN LOM METADATA STRUCTURE

Group Name	Description
General	Descriptive general information of a learning object as an unit
LifeCycle	Features related with the learning object life and present state and those entities who has taken part in the creation, edition or evolution as authors, editors, etc.
Meta-metadata	Information about the creation of the learning object metadata.
Technical	Learning object requirements and technical features
Education	Conditions, properties and needs which cover the learning resource in an educational context.
Rights	Using conditions related with copyright and licenses for the resource use.
Relation	Types of relation between the learning object and others.
Annotation	Commentaries about learning uses of the digital object.
Classification	Subject description and ontologies family belongings with the specification of the Ontology used.

In the metadata structure, it's permitted the use of multiple values in metadata fields. This is contrary to [2] Dublin Core or LOM standards recommendations but it's justified, due a more compact database. To distinguish every elemental data, a kind of "*flag*", determined by a separation character as ";", has been used in the multiple value fields. So every value can be differentiated. In a further process, the elemental values can be disaggregated by means of the execution of a specific-purpose text treatment software, which reads every multiple value, extracts every elemental value and keep it in reference with the code number given to the belonging document.

In order to maintain the links between the metadata, the database evolutes to a multiple relation tables, in which the main table sustain the total amount of data indexed by a key field (the code of the document) and every complementary table offers a partial group of metadata linked by the same key field. Examples of these complementary tables are the Authors table, the bibliography table, the organizations table, etc.

The metadata extraction process has used, as a means of containment, several related tables from a created "ad-hoc" ODBC means database, in which each field is a container element of everyone of the metadata, whether multiple or single type.

IV. THE CONVERSION OF TEXTS INTO METADATA FILE ELEMENTS

To carry out the conversion of metadata placed in the database to the respective metadata files associated with digital objects, a software tool has been created for generating XML files [3]. The methodology, as well as their functional features, responds to an open schema, which is exportable and adaptable to other systems for metadata creation.

As a first approach to the process of creating XML metadata files, the application that has carried out this work, named the Shuttle [10], has got the tables contents as data source to keep all the organized metadata in the database, providing a open starting solution to any type of process because the Shuttle is universally adapted to any database by means of a multiple configuration definition, regardless of their size and whatever their structure.

Basically, the Shuttle program will open the database, connect to the table where metadata are contained and extract the field values in every record. As a means of data output, the values are sequentially inserted in an XML template file, where each metadata accommodation are equipped with a denomination composed by a label and a decoy as a lure, available for the recognition of the tag where the metadatum has to be inserted.

Successively, after replacing the lure with the metadatum and after filling all the places the Shuttle closes the XML file, giving to it the same name as the digital object reference, which is really recorded in the field "*File*". To illustrate the general process of operation, a block diagram has been shown in Figure 2 where the Shuttle data flow operation is defined.

To diversify the applications and uses of the metadata contained in database beyond TAEE frontiers, such as repositories or digital platforms, it has been thought the implementation of a complementary function in the Shuttle to perform XML files under IEEE-LOM standard. The functionality doesn't vary, with an exception: the treatment of the multiple data fields. It's recommended by IEEE-LOM the use of single-data fields, so then the cited complementary function has to implement a new procedure just only with the multiple-recorded metadata.

In the case of moving multiple data, given it's not permitted, they can't be extracted from the main table fields. It's necessary to switch the input data to the complementary database tables. As a simple solution, it's has been decided to give this function to the templates. Instead of doing a one-way data direction between the Shuttle and the template, it has been inserted some specific procedures in the templates, so then every time the Shuttle tries to insert a multiple metadata content in a single field, the template make an interruption to switch to the respective single-data content table. Then, this table is the only data source during this partial procedure.

The performance of this data flow double implementation generate XML file with both coexisting single-data and converted multiple-to-single data.

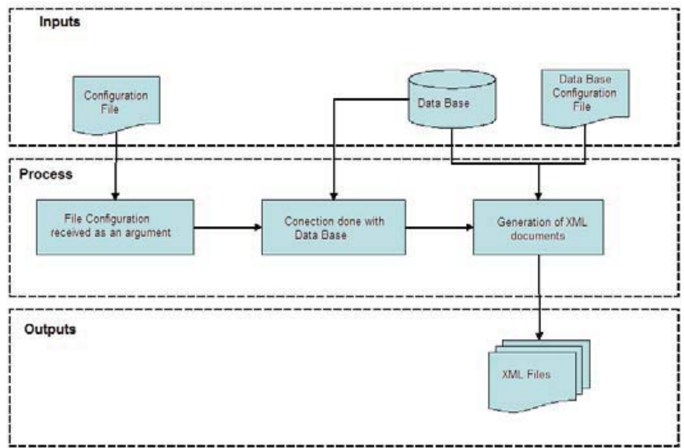

Figure 2. Block diagram of the operation of the application Shuttle

The execution of the Shuttle application has been implemented for the generation of 964 XML files that comprise the main learning objects, having made 34 metadata insertions per document. In various tests carried out under these conditions, it has been obtained an average running time of 2 minutes and 2 seconds, which means that a XML document has been created in 126.56 milliseconds average. In a subsequent set of tests, the same operations have been conducted on 4441 metadata files from the additional components.

Under similar conditions, the average running time has been 7 minutes and 55 seconds, giving a period of 107.96 milliseconds per XML file. This divergence between time values is due to latency and delay times outside the program execution. Applying linearization calculations in the Shuttle application behavior, it has been determined a performance average delay time of 6.03 seconds for each set of 1000 generations and an estimated average time of 101.52 milliseconds per XML file.

V. THE APPLICATIONS DERIVED FROM THE FILE STRUCTURE

The achievement of the processes set up to this point, a files structure of objects and associated metadata has been obtained. It can be said that at this point, the first goal of unification, standardization and labeling of TAEE documentation has been overcome, giving way to the second phase consisting of the dissemination of contents. It has, therefore, been necessary to create a file structure that can be adapted to both consequential actions: the creation of a Web that contains the information hosted on TAEE metadata and digital objects themselves and secondly, the bulk of the structure in institutional repositories and educational platforms.

To perform the first action on the Web site creation, and given the number of objects to handle, it has been taken the decision to create a specific Java software, which from the data contained in the database, will be able to generate static web pages to host the metadata and lead the user to each of the digital objects. The production process has led to an amount of web pages, one per congress, which provides information not only general but structured according to congressional sessions as divisions of every congress. Thus, by navigation through the site, it’s possible to access in a few steps to both digital object as well as the defining tab of each learning object.

Figure 3 shows a representation of the different actions performed by the application made for automatic generation of pages, on which insertion of formats and attributes has been later applied.

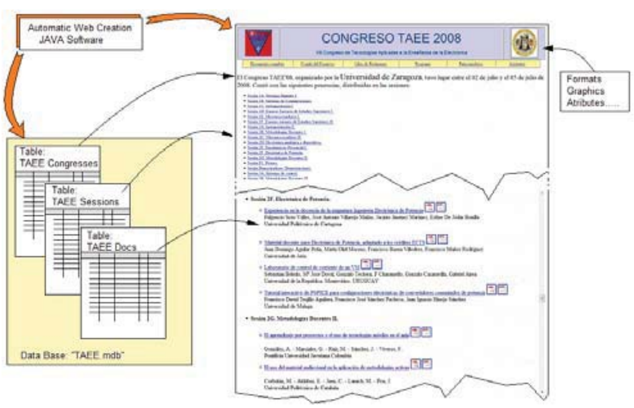

Figure 3. Website of congress and actions of its formation

In this figure 3, it can be seen that accessing the metadata central database, different page sections have been put as the header information, the list of sessions equipped with navigation and internal links, the list of documents that compose the session with the author information, the publication date and the figures which let to access to the digital object (PDF) and to a digital object form created as a result of the application of an XSL transformation exerted on each XML document. The implementation of the XSL transformation over XML files results in an XHTML page.

In order to spread the digital objects furthermore, a process of dissemination of digital objects from TAEE has been carried out through institutional repositories. Due to the amount of objects, a kind of bulk has been performed in our university's institutional repository, eSpacio-UNED [15], located in the web site http://e-spacio.uned.es as a means for the storage and distribution of digital objects, using open protocols like OAI-PMH [11]. The integration of the resulting objects has generated in the environment of the repository a number of elements making up every digital object structure. Thus, the components associated with the digital object are: a component of LOM metadata, a component of Dublin Core metadata derived from the LOM description, a component linked to the URL of the digital object itself and a component of the relationship of that object to other TAEE objects. This means that every digital object will have an own configuration collection, whose handling and visualization is possible by assigning a persistent URL to every one of the components of the object and the object itself. This allows the access to both learning object and its components, not only from the environment of the repository, but so foreign to it. By "*foreign*", it’s meant to be incorporated into the elements likely to be found by the searching engines available on the web as Google.

To improve the access to objects, like through TAEE web, it has been developed an user interface to access TAEE data located in the repository. In that interface, XML data has been used as site backbone. By means of “*adhoc*” style sheets transformation and cascade style sheets, it has been possible to conclude the interface attending to the repository philosophy. An illustration of user interface homepage has been shown in figure 4.

Figure 4. Main page from TAEE interface in the institutional repository in UNED

To access into the repository and have a view to the contents, it can be reached through the site http://espacio.uned.es:8080/fedora/get/taee:Congreso/demo:Collection/view . From the main page, the navigation links can redirect the user to any content in a specific congress, as well as, to invoke a query by means of a searching tool to find any TAEE object. As an alternative, the eSpacio-UNED list of services can be used, so in TAEE limits as in any other kind of object in any other collection.

VI. Analysis Developed in Relation of Metadata and TAEE Digital Objects

By using the data obtained throughout the described phases in this paper, a study and subsequent analysis of metadata [7] has been carried out, in order to get statistics to highlight various aspects. In the horizon of the analysis, it can be found the performance and TAEE usefulness as a meeting place for organizations focused on researching and teaching electronics. Therefore, the issues arised by the analysis can be describe as:

a.- General aspects related to conferences organization, regarding proposed themes, number of presentations and reports, etc,

b.- An study of the thematic issue in TAEE, focusing it on two fronts, the analysis and use of ontology inside TAEE and the analysis of the keywords in documents,

c.- Temporary changes in subjects from three viewpoints: thematic evolution over time, abandonment of different obsolete topics and emergence of new themes and issues with the use of new devices, techniques, methodologies, etc,

d.- Study of participating authors and organizations and their relationships to each other, deepening their relationship with common themes, the degree of collaboration between them, and so on.

Therefore from the analysis of the suggested points, the main objective of the works is achieved by means of a detailed knowledge of the data generated from TAEE reusable learning objects. This analysis is related to a meta-analysis [8] made together this project as a comprehensive study of the contents with the purpose, additional statistical analysis, identification of the path along TAEE conferences, but mainly specializing in a relationships study among participating organizations. Thus, among the obtained outcomes, it was found some organizations which serve as connecting node between gateways of knowledge, so as other ones have been identified as organizations which operate as islands or terminals. This central organizations are the most prolific and matches with those who have taken part of some TAEE organizing committees.

In a first approach to the subjects treated in TAEE, a general study has been made of the digital objects dedication, using the TAEE ontology, using the data extracted from the themes in every TAEE publication. A general data distribution can be observed in figure 5, where a circular graphic has been exposed to define the dedication of publication in nine main blocks. Each sector in the graphic represents the total amount of papers in relation to every subject.

From figure 5 picture, a first interpretation from data can be extracted: there are two main thematical blocks in which, at least, are grouped the 66% of the whole documentation. These blocks are Learning Software Tools and Educational Topics. The remaining ontology families has a much lower ontological resulting dedication value, with the exception of the family that brings together analog, digital, communications and energy systems.

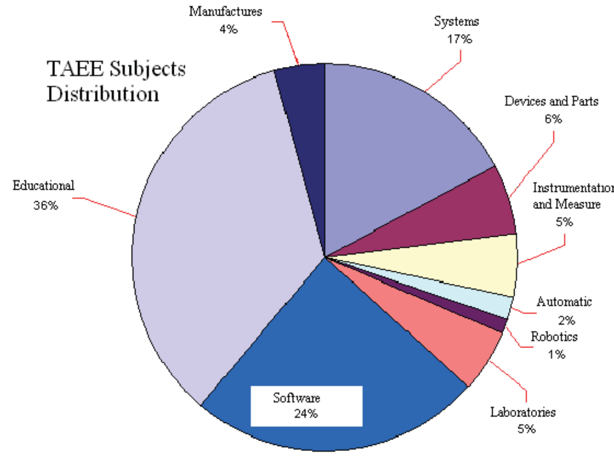

Figure 5. Thematical distribution about TAEE presented papers

Generalizing in TAEE subjects by a triple-block grouping, i.e., clusters which define thematic dedication in Technical, Educational and Software blocks, it's observed an almost exactly division in overall numbers. Using this division, it can be done an evolutionary study over time. This has been shown in figure 6.

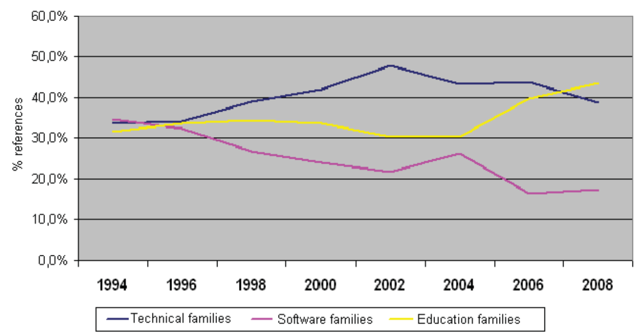

Figure 6. Temporal evolution of thematic division in TAEE

In that figure, it can be observed a similar beginning dedication in 1994 congress. Every one of the thematic blocks evolutes in a different way through time. In the first track, between the 1994 and 2000 meetings, the Technical branch has an increasing behaviour, driven primarily by publications with reference to digital systems and laboratory utilities. The Educational branch maintains the numbers of editions, mainly related to learning methodologies and learning based in practises. In a third place, Software family, tends to decrease about ten points, despite the growth in the use of related Internet tools.

Since 2002 conference, there's a new scenario and it can be observed an oscillating behaviour in the dedication of papers subjects. A growing tendency starts in relation to learning subjects, mainly driven by changes in legislation and education management system, which requires an adjustment in the departments organization in order to create adapted materials in new learning environments. On the other hand, in families dedicated to learning software and technical systems there is a downward trend. The final situation after the conclusion of the last meeting in 2008 leaves asymmetrical figures from the first congress in 1994. In the last conference, the rough division in the dedication is subject to 40% respectively for the families of teaching and technical systems, while reducing the dedication of the family of software tools slightly below 20%.

To access to further conclusions and data, the authors encourage to those interested in deepening reading the complete information from the annalysis, which is available in the Electrical and Computer Engineering Department Web site in UNED.

VII. CONCLUSION

The content of this document offers the work done on the processing of information generated at TAEE congresses. The general objectives consist in the creation of a unified and structured information environment from the documentation generated in TAEE. XML files have been created in connection with every digital object extracted from the general documentation, and it has been used in further utilities. These utilities have been defined as ways for disseminating TAEE information and documentation. In a first instance, it has been developed a common Web environment, in which TAEE services and links have been centralized and which sustain searching tools that favors the thematic consultation of the documentation.

To spread TAEE documentation beyond its frontiers, it has been necessary to make an adaptation of TAEE information to metadata standards in order of promoting online presence through hosting on documentation in repositories. This documentation hosted in educational platforms permits the creation of taylor-made courses, by means of TAEE objects converted in reusable objects.

In a parallel way, it also has been studied the performance of TAEE through its conferences by means of a content analysis of its digital objects through which it's likely to identify the path TAEE has taken, the relations between the organizations and agencies who has taken part of TAEE, as a social network and the methods and procedures carried out in greater profusion in the field of education.

The achievement of the objectives aims TAEE to enhance as Internet social network by adopting the measures applied to documentation and adaptation to the appropriate standard formats. Thus, it aims to provide the public and interested academic, the digital learning handled, allowing the reuse of materials generated as a source of knowledge.

ACKNOWLEDGMENT

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In memoriam of Tomas Pollan a good friend and a best colleague.

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VIRTUAL ANALOG AND DIGITAL COMMUNICATIONS LABORATORY: LAVICAD

On line interactive tool for learning communications systems

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***Abstract*— The virtual analog and digital communications laboratory LaViCAD has been designed at the UPC and it results a useful tool to verify different communication systems performance and also signal processing techniques, subjects given in courses typically included in the curriculum of any electrical engineering degree. LaViCAD tool has become a flexible, sustainable and on-line freely offered educational platform and it can be updated whenever new content is required. At pedagogical level, the use of a virtual laboratory facilitates the learning of certain matters, acting as a connection between the theoretical contents of a communications system course and their practical understanding and experimentation. Furthermore, LAVICAD provides resources for professors to organize different teaching activities in their courses. These activities can be used in different environments as for instance in a classroom given in the context of a full attendance course or in a homework activity at a distance learning course.**

The aim of this paper is two-fold: On one hand to describe the main technical features that make LAVICAD an original fully re-usable and reprogrammable tool in signal processing and communication systems courses. On the other hand to show some preliminary academic results obtained with the use of LAVICAD verifying how it improves the level of success.

Keywords-component; Virtual Laboratory, e-learning, re-usability, User friendly environment, Web-based labs.

I. INTRODUCTION

Some theoretical concepts and definitions in a communication system course contain a high level mathematical background. Sometimes the students must develop long paragraphs of mathematical formulas in order to demonstrate a theoretical result. In general, in a basic communication system course the student is faced for the first time to topics that are classified as very difficult by the students. As opposite, when they experiment in an instrumental laboratory, they can verify some implementation errors and misalignments that are inherent to hardware or real time software applications. In this context a graphical and interactive simulator tool can help them to understand better the differences and the similarities between a theoretical result and a real experiment. An accurate designed application tool available to verify a great diversity of communications systems and subsystems can become a powerful and useful learning help. The key idea of the use of LAVICAD consists in its functionality as a bridge from theory to Lab experiments. This idea is shown in Figure 1.

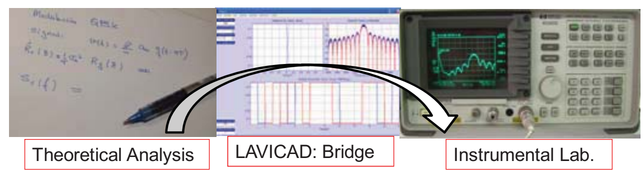

Figure 1. Key Idea: LAVICAD as bridge from theory to practice.

In the last years, the use of virtual labs has spread the engineering education environment with some innovative teaching techniques. Some experiences applied to signal processing and communication system have been presented in [4], [5] and [6]. With LAVICAD, two main advantages are fulfilled. On the one hand the reusability feature to generate whatever new exercise is proposed by the teacher, on the other hand some of the LaViCAD experiments are freely offered in an educational moodle based platform: comweb.upc.edu. The user can access and execute locally without any other software requirement than the JVM (Java Virtual Machine).

The simulation tool LAVICAD has been created to serve in the learning process of the most important basic topics and the most popular advanced topics integrated in a second-year graduate-level course in electrical engineering. The great variety of situations, flexibility and possibilities of emulating the different and not always predictable practical effects in a real laboratory, make of this virtual laboratory a powerful tool that faces the student to problems with different difficulty levels. This tool also constitutes a challenge for educators, who can consider it as a complement or as a substitution of a real and experimental laboratory.

From a user point of view, LAVICAD is formed by an on-line set of four generic and basic communications systems (Digital Modulation, Analog Modulation, etc..) and two popular communications system physical links systems (WiFi and the digital video broadcasting DVD for digital terrestrial television) . Consequently, up the date there are six LAVICAD Link Level Simulators (LLS) currently working.

At technological level, all the programmed LLS share a common and structural Java architecture. In order to create a new LLS, a general reprogrammable platform or “container” was designed and programmed at the LAVICAD starting time.

Paper Outline — after an introductory section, a description of the laboratory tool programming process is presented in section II. In section III we present three cases of use for three kinds of learning activity with different degrees of user interactivity. Section IV is dedicated to explain as the use of some LaViCAD systems in a theoretical and practical communications course has improved the academic scores. Finally, some conclusions are presented in section V.

II. Laboratory Tool Design

This section is dedicated to explain the main design guidelines for the LAVICAD tool.

A. Program Structure

To understand the structure design of the LAVICAD tool it is necessary to take in mind how a communication system works. A typical communication system functional diagram is composed by a set of basic elements sorted from first to last. Each basic element represents a step. An input signal is processed sequentially through all the steps to produce an output signal. Typically the input signal is produced by an information source and the output signal is registered at a destination terminal. The general pattern for a general communication system is shown in Figure 2. In the figure each step is characterized as a closed box. The input signal to each step (box) is the output signal from the previous step (box).

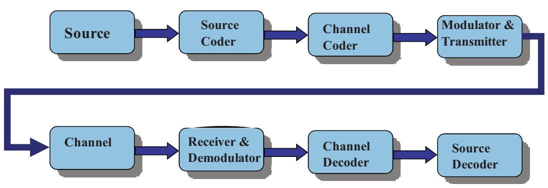

Figure 2. General Communication System functional diagram.

Each one of the experiments that integrate the LAVICAD tool represents a System Link Level Simulator (LLS). All of them admit the pattern shown in Figure 2. Each LLS emulates a different communication system or a subsystem. Depending on the process to be executed on the signal, each step is configured by means of a configuration parameter set and each step produces a set of numerical and graphical results.

Each step represents a single simplified subsystem and illustrates a part of the complete LLS. It processes the signal resulting from the previous step. The signal process is developed attending some configuration parameters. The new processed signal is analyzed in order to present the screen different graphical and numerical results and it is transmitted to the next stage.

Summarizing, there is a set of sequential actions that are developed with each step or stage:

- Acquire the signal from the previous step: Input Signal for the present step.
- Acquire the configuration parameters for the present step. These configuration parameters are introduced by the user by means of a user friendly interface window.
- Process the input signal in order to obtain the output signal.
- Analyze the output signal and present numerical and graphical results.
- Deliver the output signal to the next step or stage.

As additional features, in each one of the stages it is allowed to exchange both the input signal and the output signal with extern stored signals.

As it can be concluded, there is a high degree of repetition when programming the different LLS, and furthermore when programming the different steps included in a LLS. In order to take profit of these features, the LAVICAD tool has been programmed following a model defined at the project startup and described in section II.B.

B. The functional structure of a Communication System

LaViCAD is composed by two different parts: a development container platform and a set of differentiated LLS.

The generic container structure is represented in Figure 3.

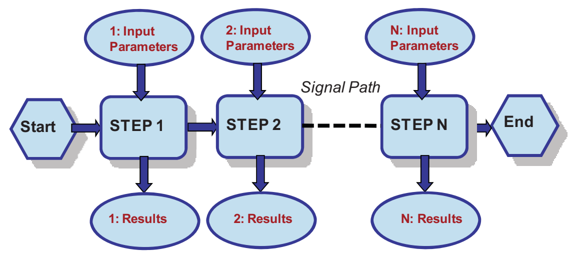

Figure 3. Container Structure.

The container platform is a Java software package that contains the guidelines and associated Java files to program the graphic interface, the variables shared between the different steps that form a LLS and the multiple menus included in each step to interact with the user. A "Container Program" has been designed to integrate all the necessary packages for actions that are sequentially executed. The application has been programmed using the Java programming language. As Java is an object-oriented programming language, the container program includes all the classes, objects and libraries necessary to execute the repetitive actions.

When a new LLS is generated it is compiled with the container platform. It has been fully documented and it is useful for those interested in creating new communications systems simulators.

When programming a new LLS, the following two phases must be followed before the compilation process:

- Phase 1: To accurately design what the new LLS must represent: Number of stages, input configuration parameters, signal processing for each one of the stage input signals and output results including numerical and graphical ones.
- Phase 2: To program all the functionalities designed in the previous phase, using, among others, the Java classes corresponding to the program container.

The set of LLS currently programmed in LAVICAD is formed by six completed LLS and two more in construction.

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C. User Interface.

From the user point of view, each completed LLS is friendly accessible from our project website [10]. When the user accesses a LLS, the main window presents him the set of sequential steps to be executed like in Figure 4. In turn, each of these steps gives access to a new interface. On this interface window the user can set up different configuration parameters, and view a wide range of results, like in Figure 5. An option provides the user with the possibility of exchanging signals with those obtained when performing a similar experiment in a different platform or just from a different LaViCAD LLS.

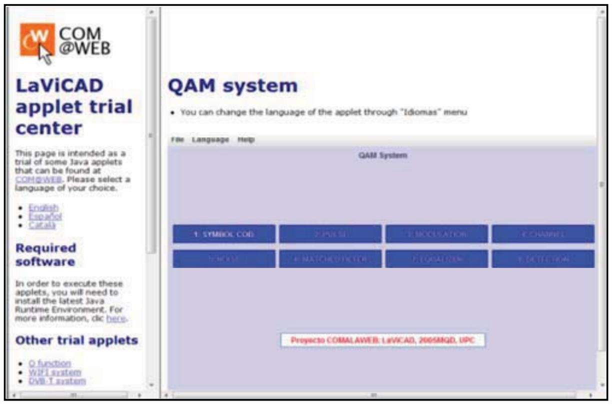

Figure 4. QAM LLS main user window.

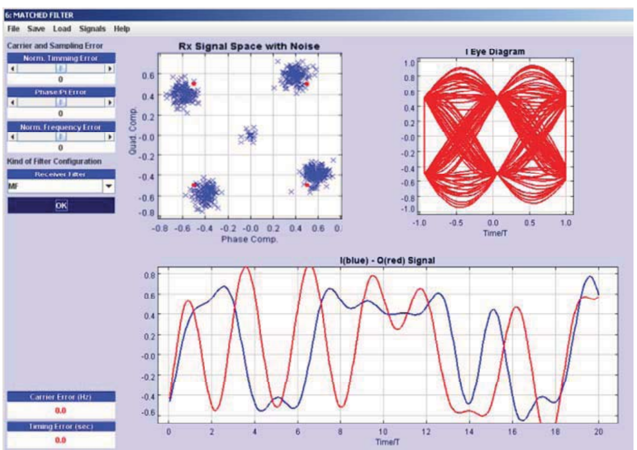

Figure 5. QAM LLS single step user window.

D. Completed Comunication Systems Simulators.

All LLS generated to date can be classified in two types: The academic ones and the diffusion ones. The academic set is used as an important support in a basic course learning process. In this case, a LLS represents a generic simple system and the steps are configured to illustrate some mathematical properties without particularizing any standardized system. They contain the fundamental basis of a certain subject in the area. They are commonly used by the students to complement a theoretical development exercise. The diffusion set has been selected to incentive the students and other occasional users with daily life popular communication applications. They are commonly used by teachers to show examples at the end of each subject that overview the scope of the initial objectives with the aim of motivate the students to enhance and expand their background knowledge on the area.

Some of the Academic LLS currently available within the application LAVICAD are:

- QAM Modulator: This system supports baseband and passband formats, RRC and rectangular pulseshape, AWGN selective frequency channel, matched filter and displaying effects produced by different kind of synchronism errors, FIR equalization and theoretical and measured Bit Error and Symbol Error rates.

- AM-FM Modulator: This system departs from an information source signal generated as a digital modulation, an audio signal or as a single sinusoid. The channel is modeled as AWGN and the demodulation can be coherent demodulation or envelope detection. There is the option to simulate non linear effects on the received signal. At the end of each stage all the signals can be displayed and the user can listen to the baseband signals.

- Channel Convolutional Codification: The main features are convolutional codes with the potential for puncturing, AWGN frequency selective channel, and soft and hard Viterbi decoding. At the last step different error measures are displayed in order to evaluate the improved performance with the use of a convolutional code.

Some of the Diffusion LLS currently available LAVICAD are:

- WiFi system, estandard 802.11g, (Physical Level): This LLS has been designed following the recommendations given by the Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications document [8]. This communication system is the basis of the WiFi connections between an access point and different terminals. It is widely used to give network access to PC terminals, laptops, PDAs, mobile phones, etc. It has been chosen for its simulation within the project LAVICAD because it is one of the most popularly used today and the population of university students is acutely very aware of this fact.

- Digital Terrestrial Television based on the DVB European standard, ETSI EN 300 744 (Physical Level): [7] Framing Structure, channel coding and modulation for digital terrestrial television. This is the TV broadcast system operating currently in Spain. It still coexists with the analogue system, but just until 2010th. Of course its popularity is undisputed.

Other LLS are currently integrating in LAVICAD but we don't describe here to not extend a lot this description.

III. Cases Of Use

The general and wide range of possibilities to be used in a learning activity offered by LAVICAD is highlighted in this section by describing three different exercises. Each one of them has been devised to be used in a different context, involving inside and outside classroom sessions and depending of the proposed activity is given in a fundamental basis course or I an application course with different degrees of interactivity levels.

A. *Acompanying a theoretical development exercise.*

This activity can be proposed for the teacher in a fundamental communication system course in order their students begin to work with spectral density issues.

By LAVICAD the user can emulate most of proposed exercises in a textbook, as for instance [1], [2] or [3]. Through the QAM LLS some exercises proposed by the author in [1] can be studied. Let's solve exercise 8.7, part 1 in page 563. The statement of the problem can be summarized as:

Problem Statement:

Consider a four-phase PSK (QPSK) signal that is represented by the equivalent lowpass signal.

$$v(t) = \sum_n a_n g(t - nT) \quad (1)$$

In (1) a_n takes on one of the four possible values $\frac{\pm 1 \pm j}{\sqrt{2}}$ with equal probability. The sequence of information symbols $\{a_n\}$ is statistically independent.

Determine and sketch the power-spectral density of $v(t)$ when $g(t) = \begin{cases} A & 0 \le t \le T \\ 0 & \text{otherwise} \end{cases}$

Theoretical Solution: The student faced to previous analysis proposal, must obtain, after some calculus that the demanded spectral-density equals:

$$A^2 \left(\frac{\sin \pi fT}{\pi fT} \right)^2 \quad (2)$$

Practical Solution: Setting adequately the QAM parameters set from the first step to the third step, the theoretical and the real spectrum for a generated random symbol sequence can be sketched as in Figure 6.

B. *Accompanying a laboratory experiment.*

A utility of interest and wide acceptance among students is the real-time comparison of results obtained in an instrumental laboratory with the use of LaViCAD. It is of great pedagogical interest to compare the different functions measured in practice, with the functions explained in a lecture session.

The use of LAVICAD in a laboratory session can serve as a complement during the experiment execution or as a previous mandatory homework to prepare the laboratory session.

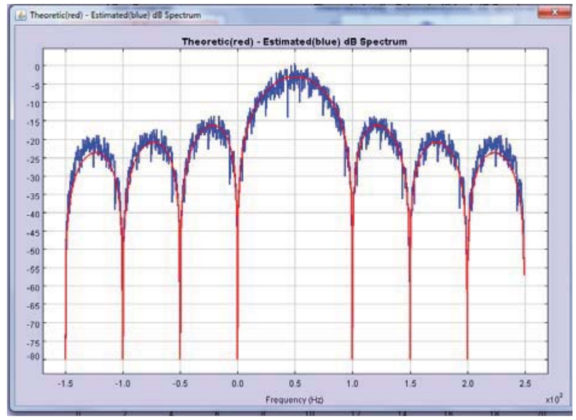

Figure 6. QAM Spectrum for the Exercise proposed in III.A.

Let's assume that in a digital modulation practice (QPSK) it is mandatory to visualize the spectral-density on a spectrum analyzer screen. The students are faced simultaneously to the theoretical spectral density generated by LAVICAD and to the measured real one, presented on the spectrum analyzer screen. They realize of the imperfections and alignments errors obtained in practice and develop their critical thinking skill oriented to analyze what causes the alignment errors.

Figure 7. Use of LAVICAD acompanying an instrumental laboratory practice. LAVICAD is being executed at he computer whose screen can be seen on the table.

C. *Use of LAVICAD in a project.*

LAVICAD can also be used in a more complex activity integrated in a project based learning course with a multidisciplinary range of areas. With the activities described in III. A and III.B the user interaction with the simulator is limited to introduce in each step the setting parameters and watch the results, and the setting parameters must be previously calculated from the exercise proposed by the teacher. The third use we propose in this section consists on the implementation of a new system or a new step. Some kinds of activity are identified and ordered from low difficulty degree to high:

- To form a new communication system by combining two or more generated LLS. In this case, the user can introduce as input signal to a LLS step the output signal obtained from a different step. Depending on the new communication system to be verified, the user must design and select the different steps to be combined in the new system.
- To modify a single step in a generated LLS.
- To add a new step to a generated LLS.
- To design and program a new LLS using the LAVICAD container application in the compilation process.

The proposed activities are helpful in a process to train the students in some general skills, as engineering problem solving, quality awareness and self learning.

IV. Preliminary Academic Results

The use of LAVICAD based learning activities has been implemented in two different courses: the course of “Communications I” and the course of "Communications Laboratory I". These courses are among the current ones in the second and third year of our studies. An introduction to digital and analogue modulations is given in “Communications I”. "Communications Laboratory I" is dedicated to develop experiments based on the theory given in “Communications I”.

In a 45 students group (2008 spring semester) “Comunications I” course, two mandatory theoretical exercises were proposed by the teacher to the students. The qualification of these two exercises represented a 5 percent of the final course score. The teacher proposed the students to use some LAVICAD LLS in order to complement the exercise development, like the learning activity described in III.A, but the use of LAVICAD was not mandatory. Two weeks later than the second activity delivery term ended there was a midterm exam to evaluate the skills of two subjects included in the course program and partially related to the proposed exercises. The qualification of this exam represented a 20 percent of the final course score. The success levels of the course are shown in table I.

TABLE I. Avaluation Results with the use of LAVICAD in the course of Comunications I

	Number of students	Midterm exam approval percentage	Final Score approval percentage
Use of LAVICAD	31	25 (80%)	20 (64%)
No use of LAVICAD	14	5 (36%)	6 (43%)
	45	30 (67%)	26 (58%)

The third row in the table shows as the success level is highly correlated with the use of LAVICAD to complement the theoretical developments

Authors are aware of the sample size is small in this preliminary startup, but after that semester, the use of LAVICAD activities has been introduced from time to time with some student groups and they have always produced results similar to those shown in the table.

The laboratory course program ("Communications Laboratory I") is composed by five subjects or experimental works dedicated to analog and digital communications. The use of LAVICAD is mandatory for all the students as an accompanying activity of the two last subjects.

With the new European higher education adaptation process startup, the contents and methodologies of both courses will be integrated in a new course, entitled “Fundamental of Communication Systems”. This course will start on February 2011 at the Escola Tècnica Superior d’Enginyeria de Telecomunicació de Barcelona - ETSETB, UPC .

V. Conclusions

The integration of the LAVICAD tool in the daily teaching activities of fundamental and laboratory communication system courses is becoming a useful resource in order to provide students with some typical engineering education skills. The tool is composed by a set of web access simulators (LLS) that can be applied to a wide range of academic or practical exercises. The use of the “Container Program” to generate new LLS results a very low consuming effort process. As a limit of use of LAVICAD there is a memory resource restriction that cannot be exceeded. This is a JVM feature and the upper limit depends on each user computer or laptop.

There are currently several e-learning tools available for academic purposes, but few of them regarding signal processing and communication systems courses. This represents one of the innovative points of this paper and can be considered as an add value of LAVICAD.

From preliminary LAVICAD experiences it can be concluded that final scores have increased when some LAVICAD based teaching activities are proposed in the course. As last conclusion, authors can assure that the student satisfaction level has also increased. This statement was deduced as a consequence of spontaneous successful students comments addressed to the teachers and referencing the LAVICAD based activities and as a consequence of the increasing number of queries presented by the students at the teacher’s office hours.

The challenge of introducing LAVICAD based activities in a communication system course consumes a great amount of teacher time and teacher effort. With the EHEA startup some new teaching uses must be renovated. In our course each teaching activity must be designed to cover some generic skills and dome specific skills and this is one of the most effort demanding features to be considered in a LAVICAD based activity design.

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Open educational resources (OER) inspire teaching and learning

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Abstract—**Open educational resources (OER) can significantly reduce the time required to prepare lectures. The prerequisites are that a desired resource can be found quickly and that its adequacy for the intended purpose can be estimated easily. Eventually, the resource should also be suitable for modification. In the first part we outline the requirements for the sourcing, storing, retrieval and exchange of open educational resources considering technical and legal aspects. In the second part we present a case study focusing on the user level perspective. We describe the searching for a particular OER (an online Moodle tutorial), the analysis of the resource found, its modification and the publishing of the modified resource on a repository.**

Keywords-open educational resources; repositories; metadata; learning objects; learning design frameworks; open access; community of practice;

I. INTRODUCTION

Imagine the following situation: A university teacher is preparing his next week's lecture. The topic is the visualization of multivariate data with scatter plots and parallel coordinate plots. He has already held this lecture one year ago. His memo of that lecture indicates that the students had some difficulties with the sketching of a parallel coordinate plot. Our teacher would like to improve his lecture with elements that involve students directly and actively in the learning process, thereby promoting understanding by doing. He has some instructive simulations in mind, exercises, perhaps an assignment. However, our teacher has neither the time nor the budget to develop the required material. Certainly, hundreds of teachers all over the world must have the same or similar needs. Probably, one or more persons have already developed an easy to use software the students could experiment with in order to better understand the use of parallel coordinate plots for the analysis of multivariate data. Let us suppose that a free Microsoft Excel add-in would satisfy the needs of our teacher. How can he find this software? In case he finds it[1], how can he quickly compile an accompanying worksheet for the students?

[1] Such an MS-Excel add-in would be Visulab® - Interactive data visualisation in Microsoft Excel (http://www.inf.ethz.ch/personal/hinterbe/Visulab/)

The amount of work to develop educational resources (e.g. documents, graphics, images, videos, laboratory exercises, compatible learning units) is high. Moreover, all these resources have to be maintained and to be developed further as technologies or curricula change. Unlike scientists, teachers are all too often "lone fighters". They do not have many opportunities to discuss their lectures and materials with colleagues, to exchange ideas or even to develop materials in a team.

This is where open educational resources (OER) come into play. OER can help teachers to reduce their amount of work for the preparation of the lectures. Open educational resources can be modified to suit the specific didactical needs of a lecture and the "producers" and "consumers" can contact each other in order to discuss modifications and extensions to existing OER.

II. WHAT ARE OPEN EDUCATIONAL RESOURCES?

The OER movement aims to break down barriers – such as teaching material locked up behind passwords within proprietary systems or filed in personal drawers – and enable sharing content freely [1].

The *openness* of OER refers to [2]:

- The freedom to use the work and enjoy the benefits of using it.
- The freedom to study the work and to apply knowledge acquired from it.
- The freedom to make and redistribute copies, in whole or in part, of the information or expression.
- The freedom to make changes and improvements, and to distribute derivative works.

Educational means that the material is produced for use in formal educational settings, although open educational resources can well be used for informal or non-formal learning outside formal educational settings [1].

Open educational resources are digitized materials offered freely and openly for educators, students and self-learners to use and reuse for teaching, learning and research [1]. An open educational resource can be:

- *Learning content* (e.g. courses, modules, learning objects, exercises, references to collections and archives).
- *Software* (e.g. development tools, tools for organizing content, simulation tools)
- *Hardware* (e.g. electronics prototyping platforms such as Arduino [3]).
- *An implementation resource* (e.g. creative common licenses, best practice design principles).
- *An interoperability standard* (e.g. the sharable content object reference model SCORM [4], the IMS content packaging specification [5]).
- *Media* (e.g. images, audio recordings, videos).

III. Institutional and National Repositories

In order to be accessible from all over the world, open educational resources must be made available on servers connected to the internet, so-called repositories. Repositories can be provided by universities, libraries, communities, national bodies or other institutions. An exemplary collection of open e-learning content repositories can be found on the website of the Open eLearning Content Observatory Services OLCOS [6].

OER repositories must comply with standards. Otherwise, only local searches on the distinct servers can reveal the "hidden treasures". The repositories must exchange the descriptions (metadata) of the educational resources stored in their databases. In this way, searching on a specific repository yields the list of relevant records from all the connected repositories. The exchange of the metadata records is accomplished by means of the open archives initiative protocol for metadata harvesting OAI-PMH [7].

A central access to all OER repositories would simplify the task of searching for a needed resource. Such a central access already exists: The OAIster® database [8]. OAIster boasts more than 23 million records representing digital resources (digitized books and journal articles, digital text, audio files, video files, photographic images, data sets with statistical information, theses and research papers) from more than 1,100 contributors. OAIster records are freely available through WorldCat [9], the world's largest network of library content and services.

Figure 1. Search box providing access to WorldCat from within the OAIster website.

OAIster is intended to be a collection of open access resources. Open access resources are primarily library resources. Nevertheless, OER repositories incorporating the standardized OAI-PMH harvesting protocol could deliver their metadata to the OAIster database and thus make open educational resources accessible through a "single-point-of-search". The resources on existing repositories that do not support OAI-PMH cannot be retrieved through searches initiated on a repository supporting the OAI-PMH harvesting protocol. What should be done with such repositories? Their technical infrastructure could be upgraded with a suitable implementation of the OAI-PMH, provided that the metadata are already present or newly entered. Alternatively, the resources could be transferred to a repository supporting the OAI-PMH. In any case, new repositories should be based on the aforementioned standards.

Furthermore, all OER repositories should internally provide their metadata in a format that allows search engines such as google, yahoo or cuil to index them. In this way, teachers, students and self-learners can find open educational resources by using their preferred search engine.

IV. Metadata and Formats

If we want to find open educational resources on other repositories than the one we are logged in, our repository must provide access to the metadata of the resources on the other repositories. As depicted above, this is done through metadata harvesting. In other words, we do not have access to the full text of those resources. And when we think of multimedia resources such as images, audio or video, it is obvious that we need metadata in order to be able to find appropriate content. Which metadata standard is suitable?

The Dublin Core metadata standard or a subset of it is a candidate for the description of open educational resources [10]. In the OAIster database, for instance, the simple Dublin Core metadata format is used. The Dublin Core provides general fields such as <title>, <creator>, <description> and <language> as well as fields specifically useful for educational resources (e.g. <audience>, <instructionalMethod>, <educationLevel>). With respect to complex educational resources such as courses or modules, there are important fields missing. For instance, no metadata fields exist for the specification of "educational objectives" or "typical learning time".

```
<rdf:Description>
  <dc:creator>Peter Noeller</dc:creator>
  <dc:title>Algebra</dc:title>
  <dc:subject>mathematics</dc:subject>
  <dc:date>2008-04-23</dc:date>
  <dc:language>EN</dc:language>
  <dc:description>
     An Introduction to Algebra
  </dc:description>
</rdf:Description>
```

Figure 2. Dublin Core metadata example (extract).

Another candidate for the description of open educational resources is the IMS metadata specification which is now aligned to the IEEE Standard for Learning Object Metadata (LOM) [11] [12]. The IMS Global Learning Consortium has specified these "data about data" in order to make the process of finding and using a learning resource more efficient. With the fields provided by the IMS / LOM metadata specification a learning resource can be described in more detail than it can be done with the elements of the Dublin Core.

Discussions with practitioners indicate that either metadata format will not be used extensively by teachers because of a significant lack of time to fill in the fields accordingly [13]. Eventually, the use of folksonomies (collaborative tagging) could improve the situation [14]. An author only provides a minimal set of descriptive fields with the educational resource when she or he publishes it on the repository. Users add appropriate tags when they find the resource. The more tags are added with time, the more relevant the results of a search for an OER will become.

```
technical.requirement.type = browser
educational.difficulty = low
educational.typicallearningtime = 00:00:10
educational.description = Explains who Frank
   Lloyd Wright was, in the context of recent
   American History. It has a portrait
   photograph and links to further resources.
educational.language = en-US
classification.keyword = architecture, chicago
school, modernist, prarie
```

Figure 3. IMS metadata example (extract).

The reuse of open educational resources further depends on reusable document formats. Material created on a Macintosh must be usable on a MS-Windows computer as well. The following formats can be recommended for reusable documents:

- Plain text: Unicode
- Images: TIFF (Tagged Image File Format)
- Audio: MP3 (MPEG-1, Layer 3)
- Video: MPEG-4

The Portable Document Format (PDF) is widely used for documents incorporating text, graphics images and even audio and video. A PDF-document can be read on every computer system, but it cannot be modified. Thus, PDF is not a suitable format for reusable learning objects. Open Office documents should be used instead.

What about HTML? HTML pages can be modified. It is relatively easy to add or remove content and to change the layout (as long as cascading style sheets are used to style the pages). Using a free Web authoring tool (e.g. KompoZer), the pages and styles can be modified even without a sound knowledge of HTML [15]. If the HTML pages and style sheets along with the images and further media should be packaged into a SCORM or IMS content package that could be imported into a learning management system, a so-called manifest file would be needed. Although the manifest is a text file written in XML, it is not easy to hand-code it. In this case, an appropriate authoring framework could be used, e.g. the ReCourse Learning Design Editor [16].

Complex educational resources such as courses and modules could be authored in XML. XML has several advantages:

- The sources are text files and can be written and modified using a simple text editor.
- XML is also the basis for the manifest file.
- Using XSL (eXtensible Stylesheet Language) transformations, the resources can be produced and published in different formats, such as HTML, SCORM, or PDF.
- The XML sources can also be written and modified using open source authoring frameworks, e.g. the Firedocs eLesson Markup Language (eLML) Editor [17].

Unfortunately, the eLesson Markup Language is not a standardized language. Educational resources written in a different XML-based learning design language cannot be edited with the Firedocs eLML editor, and vice versa.

V. Reuse of Educational Resources

Before they can be reused, open educational resources must be found. (We talk about reuse because we defined OER as materials produced for use in formal educational settings. Thus, the publication of the resources on repositories allows their reuse.) We already discussed the respective prerequisites (repositories, metadata exchange, search engine indexing, reusable document formats).

Anyway, who is interested in reusing educational resources? The intention of open educational resources is the reuse by other teachers. The promise is that the teachers can significantly reduce the time required to prepare lectures. The resulting variety of materials (and didactical concepts) also stimulates students. However, according to [18] only 15.3% of the users of MIT open course ware content are educators. 31.4% are students and 48.2% are self-learners. Why do only few educators reuse open educational resources?

The granularity of the resources could be a reason. It could be harder to integrate resources with coarse granularity (e.g. complete courses) into ones lectures. An expressive graphic or a table with significant data can be reused more easily than a complete online course or the recording of a two-hours lecture. The findings of [17], however, indicate that resources with fine granularity (e.g. images) are not reused more often than resources with coarse granularity. The determining factor for reuse with respect to granularity seems to be the *reuse context*. Resources with a slightly lower granularity than the object that has to be developed are easier to integrate than resources with much finer granularity. For the development of a course, for instance, the integration of a complete lesson is more convenient than the reuse of a single image.

Several teachers do not often reuse open educational resources because of technical barriers (e.g. no access to the repository, wrong document format). The most important obstacle is the difficulty to find the needed resources. This is mainly due to the lack of appropriate metadata. Eventually, a teacher, who is searching for a video with experiments regarding the psychology of human perception, really finds one. The duration of the video is 47 minutes and there are no descriptions of the individual scenes and no specifications of their beginnings and endings. The teacher does not have time to inspect the whole video and resigns the reuse of that resource.

First of all, teachers must make their own resources available. Otherwise, the OER movement will not be successful. Many teachers express certain reserves towards the publication of their own material. Some of them fear the criticism of the colleagues. Others complain that it would not be fair to freely reuse their material which they have worked very hard for. Some teachers worry about the time required and the cost of obtaining permission for using assets in their material (mainly graphics and images, audio and video content) for which a third party owns the copyright. On the other hand, teachers get personal satisfaction when they make their materials publicly available. They gain reputation. Authors of open content would like being personally rewarded through workplan, promotion, awards etc. for the use of their material and being acknowledged as the creator, especially when the resource is adapted or changed [1]. In any case, teachers must be encouraged to supply their materials and the institutions must setup the accompanying measures in order to support the authors of open content.

VI. CASE STUDY

At the University of Applied Sciences *HTW Chur* we currently use Claroline (Classroom Online) as learning management system [20]. In autumn 2010 we will introduce Moodle for the first-year students in the master program in information science [21]. The students enrolled in the further programs (business administration, tourism, civil engineering, electrical and electronics engineering, and media engineering) will follow in 2011. The faculty involved in the master program in information science has to become acquainted with the basic concepts and the efficient handling of Moodle's functions before the beginning of the new academic year in September 2010. During the first week of the fall semester, the students have to learn how to work with the Moodle platform. The respective introductory courses have to be repeated every year. Therefore, a blended learning course would be adequate. With two face-to-face lessons we could shortly summarize the concepts of Moodle and the peculiarities of the configuration at the *HTW Chur*. We could go through an exercise so that the participants could get to know the relevant functions. Consequently, the exercise would be different for the faculty and the students. Afterwards, an online course for the faculty and another one for the students could give them the opportunity to further study the effective use of Moodle for teaching and learning. The online course would also allow the faculty and students to have a look at individual topics at anytime whatsoever and to become acquainted with them on own accord.

The planning and realization of such an online course is both, time-consuming and costly. However, Moodle is widely used at universities all over the world. Thus, we expected that at least one adequate Moodle online tutorial would be available as an open educational resource.

A. *Finding resources*

The prerequisites were that the language of the educational content was German and that the online course was suitable for the training of both teaching staff and first-year students, or that the content should at leat be suitable for modification. Thus, we first searched the Swiss national learning object repository SWITCHcollection [22]. Unfortunately, we did not find a Moodle tutorial there. SWITCHcollection is a relatively new repository and does not yet contain many resources. In a second step we used the phrases "open educational resource" and "online tutorial" to search for pages in german with google. The search yielded 3 hits only! We changed the phrase search into a separated keyword search ("open educational resource online tutorial") and found at the first place among 15'300 pages the Moodle online tutorial on the web site of the institute for research in open, distance, and e-learning (IFeL) at Brig, Switzerland [23].

B. *Analyzing the resource*

The Moodle tutorial is hosted on the Moodle server of the institute IFeL. It is freely accessible over the web and the learners also get a free user account in order to work on the exercises and assignments.

Figure 4. Online Moodle tutorial (introductory page)

The tutorial comprises eight modules: Basic concepts, course configuration, content distribution, communication with students, collaboration, exercises & assignments, reflections, user administration. The intended audience is the faculty. Although the Moodle tutorial has not been published on a repository yet, its sources are available under the creative commons licenses BY (attribution) and SA (share alike) on the corresponding website. (The authors intend to publish the Moodle tutorial on SWITCHcollection in due time.) We downloaded the sources and inspected them. Unexpectedly, there was also a tutorial for students included in the download package.

Does this resource suit our needs?

- The language of the educational content is German.
- There are two different tutorials, one for the faculty and the other for students as intended audience.
- The modules of the tutorials follow an intelligible didactical concept. The front page of every module lists concisely formulated objectives and the approximate time needed to complete the module. The content is structured according to the ECLASS model [24]. An ECLASS module is partitioned into five (eventually six) sections: Explain (overview), clarify (requirements, recommendations), look (review examples or samples), act (practice what has being taught), share (student interaction), self evaluate/ submit (self-evaluation and submission of completed work); eventually, a summary concludes the module.

E xplain
C larify
L ook
A ct
Share
S elf evaluate / **S**ubmit
(**S**ummary)

Figure 5. The ECLASS model (modified).

The tutorials come up to our expectations. Metadata would have been desirable in order to get a quick glance at the objectives and the overall time needed to complete the tutorials. These metadata should be added to the resource when transferring it to the SWITCHcollection repository.

C. Modifying the resource

The tutorials have been developed on the basis of eLML, the e-Lesson Markup Language [25]. The sources are written in XML and can be modified with any ordinary text editor. Structure, content and form of the tutorials are separated from each other. Using XSL transformations, the content can be published either as HTML pages, as SCORM-compatible content package or even as a PDF document. Besides the XML sources, the download package also contains the HTML derivatives.

We already had some experiences with learning resources based on eLML, but we were unsure whether or not the modifications of the eLML sources of the Moodle tutorials could be modified easily. We wanted to know more about it and contacted one of the authors. This was possible because the e-mail addresses of the team members who developed the tutorials were published on the entry page. The discussion with that person revealed the pitfalls of the eLML technology. At least one member of the development team must be a technician who is familiar with the eclipse development framework. Otherwise, the modifications of the sources (content, cascading style sheets, XSL-transformations etc.) would be rather complicated.

```
<unit label="goals" title="Ziele und Inhalt"
<learningObject title="">
   <clarify>
      <paragraph>In diesem Tutorial ...
      </paragraph>
      <list listStyle="ordered">
          <item><link targetLesson="moodle1">
          Grundaufbau und Basiseinstellungen
          </link></item>
          <item><link targetLesson="moodle2">
          Organisation und Administration
          </link></item>
      </list>
      <paragraph title="Aufbau">Das Tutorial ...
      </paragraph>
   </clarify>
</learningObject>
```

Figure 6. eLML source text (extract).

We had three options to proceed:

- The faculty could use the existing online tutorial hosted on the Moodle server of the institute IFeL. We would provide additional material with explanations of the specifics of our own Moodle configuration. The tutorial modules for the students could be published on our own web server.
- We could modify the existing HTML pages of both tutorials and publish them on our own web server.
- We could plunge into the technical details of eLML and the eclipse framework and modify the XML sources and XSL transformations according to our specific needs.

We decided not to alter the XML sources but to modify the HTML derivatives and publish both tutorials on our own web server. In this way, we do not need to modify the XSL transformations which would be needed to generate the HTML pages from the XML sources. Modifying the HTML pages is the easier approach but its drawback is that our modifications cannot be directly fed back into the original.

What were the modifications to be carried out?

- There were some typing errors on various pages of the tutorial. Correcting them was easy.
- The layout should reflect the corporate design of our university. Thus, the cascading style sheets had to be modified accordingly.
- The entry page of the tutorial should summarize the content and let the users select the faculty part or the students' part. It had to be designed from scratch.

- A presentation of the didactical concepts that can be supported through the configuration of a Moodle course is missing. It has yet to be developed.

To modify the HTML pages and the cascading style sheets was quite easy. However, to understand the structure of the pages and the navigation mechanisms was cumbersome. We had to inspect every single file and to sketch the relations between the HTML files and the style sheets in order to find the position for a particular modification. A concise documentation of that structure and the individual files would have been very useful.

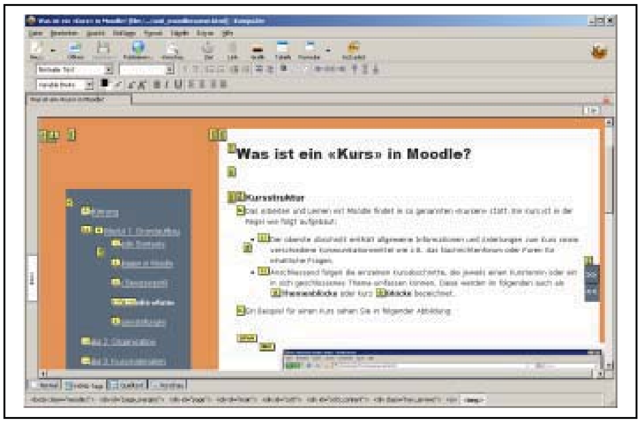

Figure 7. Modification of an HTML page using the free web authoring tool KompoZer [24].

Figure 8. New Moodle tutorial entry page.

D. *Publishing the new resource*

In order to give our work back to the community, we have to publish it on an institutional or other repository. We decided to publish our open educational resources on the SWITCHcollection repository.

The publication of an educational resource should be as easy as the download of a resource from the repository. Thus, we implemented the harvesting interface between our learning management system Claroline and the SWITCHcollection repository. Our faculty can transfer resources from Claroline with the “click on a button” [26]. It is most convenient to package the content (e.g. the HTML pages and stylesheets) along with the metadata file and the documentation into a zip-archive. Alternatively, the resources could be arranged in a SCORM or an IMS content package. In this way, only a single file has to be transferred to the repository. Before transferring the resource, a metadata form must be filled in. It is most important to precisely describe the resource in detail. Otherwise, it would be difficult to find it in the repository as the individual contents of a zip-archive, a SCORM, or an IMS package cannot be found by the repository’s search engine.

The SWITCHcollection development group is working on the refinement of the metadata fields and the definition of their meanings. We are contributing to this work because meaningful metadata are crucial for the enduring success of open educational resources.

VII. CONCLUSIONS

In order to be found and widely reused, open educational resources must include three elements: The content itself, appropriate metadata, and a documentation (at least a sketch) that points out the structure of the resource from a didactical and a technical point of view. The resources must be published on servers that comply with open access standards (such as the Open Archives Initiative Protocol for Metadata Harvesting) and include Web 2.0 functionalities (such as comments). Educational institutions must support their faculty in the production and publication of open educational resources and last but not least the establishment of a community of practice would be of great value within and amongst institutions.

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Session 03A Area 2: Innovative Competitions and Laboratories - Detectors and robotics

Developping of Low Cost Capacitive Sensors for Laboratory Classes
Marcos, Jorge; Pérez-López, Serafín Alfonso; Quintáns, Camilo
University of Vigo (Spain)

Development of a Wiimote-based gesture recognizer in a microprocessor laboratory course
Fernandez-Rodrigues, José Ángel; Lorente-Leal, Alberto; Montero, Juan M
Technical University of Madrid-UPM (Spain)

Hands-on intelligent mobile robot laboratory with support from the industry
Chuang, Sheng-Hsiung; Huang, Hsin-Hsiung; Huang, Jheng-Yu; Lee, Chyi-Shyong; Su, Juing-Huei
Lunghwa University of Science and Technology (Taiwan, Republic of China)

Cybertech: Robotic Competition and Subject
Galán, Ramón; García-Borrás, Patricia; García-Robledo, Pablo
Technical University of Madrid-UPM (Spain)

Developing of Low Cost Capacitive Sensors for Laboratory Classes

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Abstract— **This work presents an approach to the education in sensors, targeted to future engineers that relies on using educational sensors. An analysis of major issues on sensor education is carried out and two types of didactic, capacitive and low cost sensors are presented, which allow the student to easily under-stand the physical principle of the measurement, as well as to evaluate other sensor features like repeatability, sensitivity and measurement uncertainty. To this aim, some capacitive sensors have been developed to measure levels of oil and water in the laboratories. In the academic year 2006-07, the Laboratory of Sensors and Signal Conditioning of the Electronic Technology Department of the University of Vigo started using those sensors experimentally. During 2007-08 and 2008-09, a methodology based on these didactic sensors, combined with signal conditioning circuits and simulations in Pspice, has been launched. Then, a signal conditioning circuit is assembled and the information displayed on a PC monitor, connected by a data acquisition system. Furthermore, this paper includes the efficiency evaluation results of the proposed methodology, obtained from student surveys.**

Keywords-capacitance transducers; circuit simulation; learning systems; level measurement.

I. Introduction

The instrumentation and measurement topics in the engineering education present big difficulties to the learning methodology, the economic cost of the materials and equipments, and the time spent in the laboratory sessions. Thanks to the advances in microelectronics in the last years, the data acquisition systems became the most economic part, with better features and easier to use by the students [1]-[3].

Advances have been outstanding in sensors as well, thus achieving more intelligence, precision and functionality. Nevertheless, from a didactical viewpoint they are still expensive, barely didactic and difficult to assemble in robust scale models. This leads the teaching staff in charge of sensors and signal conditioning laboratories, to make continuous efforts to ease the study of sensors. Therefore, a major objective of the Electronic Technology Department of the University of Vigo is developing low cost didactic sensors and signal conditioning circuits, friendly to use by the students and to teach the physic principles of sensors [5], [6].

This work presents a group of capacitive sensors fabricated from common recycled materials, familiar to the students. In particular, there are two types of capacitive sensors for the level measurement:

- Flat capacitors constructed with a Compact Disc (CD) box, to which the capacitor plates are attached. The plates are made of aluminum covered with laminated plastic.
- Cylindrical capacitor made off two different pieces of copper pipe, constructed in a coaxial way.

In order to be handled in the laboratory, the flat sensors have been placed in already available scale models, even though they can be easily mounted in low cost homemade scale models with a simple container to hold the capacitor. These sensors will permit the measurement of water level. The cylindrical capacitor has been assembled in a homemade scale mod-el to measure the oil level. The students have characterized four different sensors and implemented two simple signal-conditioning circuits of first order, one active and the other one passive. The next section describes the implemented sensors and their characterization according to the teaching methodology followed.

II. Characterization of the Sensors Developed

The changes of a physical variable, in this case the liquid level, causes variations in the dielectric, such that when the level is zero the dielectric is air (ε_{air}), but for a certain level h of liquid, a portion of the dielectric is still air but the rest is liquid, whose level will be measured. Thus, the changes in the dielectric cause changes of capacity for this type of sensors. The capacity also depends on the capacitor area and the distance between the plates (Ec. 1).

$$C = \varepsilon_0 \cdot \varepsilon_r \frac{A}{d} = \varepsilon \frac{A}{d} \qquad (1)$$

A. Level measurement with flat capacitors

This type of capacitor is constructed with a CD box, whose interior sides are attached to the plates. These are made of aluminum covered with laminated plastic. Several prototypes have been developed; Fig. 1 shows an image of one of them and Fig. 2 another one, whose plates are formed by three triangles. The plates are cut out and only two little "wings" are left for external connections. Thus, the capacitors consist of two parallel plates separated a certain distance "d" given by the type of CD box used, which can be normal (d~5 mm) o narrow sized (d~2 mm).

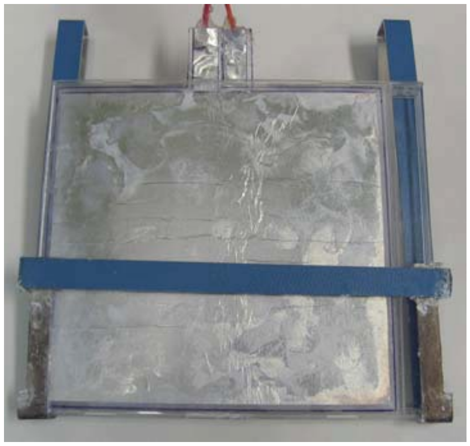

Figure 1. Normal flat capacitive sensor based on a CD box.

Figure 2. Flat capacitive sensor of triangles based on a CD box.

In order to analyze the sensor operation, the portion of the plates with air as dielectric is considered in parallel with the one dipped, according to the level of liquid that is being measured (Fig. 3). Since capacitances in parallel are additive, the general expression (2) is obtained from (1). The expression demonstrates that the sensor characteristic curve is linear, so the response does not have to be linearised in this case.

$$C_{Total} \cong C_{aire} + C_{liquido} = \varepsilon_{liquido} \cdot \frac{a \cdot h}{d} + \varepsilon_{aire} \frac{a \cdot (b-h)}{d} = \\ = \frac{a}{d} \cdot \left[h \cdot \left(\varepsilon_{liquido} - \varepsilon_{aire}\right) + \varepsilon_{aire} \cdot b\right] \quad (2)$$

In the sensor of Fig. 2 the capacitor plates consist of three triangles each one, which present characteristic curves of second order (3) for the capacitors C_1, C_2 y C_3 (Fig. 4), so the students will take into account this non-linearity.

$$C_1 = C_3 = \frac{a}{4 \cdot d} \cdot \left[h^2 \cdot \frac{\varepsilon_{liquido} - \varepsilon_{aire}}{b} + \varepsilon_{aire} \cdot b\right] \quad (3)$$

$$C_2 = \frac{a}{2 \cdot d} \cdot \left[\frac{(b-h)^2}{b} \cdot \left(\varepsilon_{aire} - \varepsilon_{liquido}\right) + \varepsilon_{liquido} \cdot b\right] \quad (4)$$

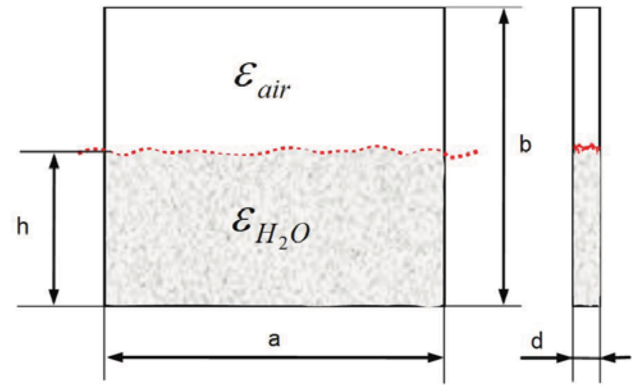

Figure 3. Top and side view of a flat capacitive sensor.

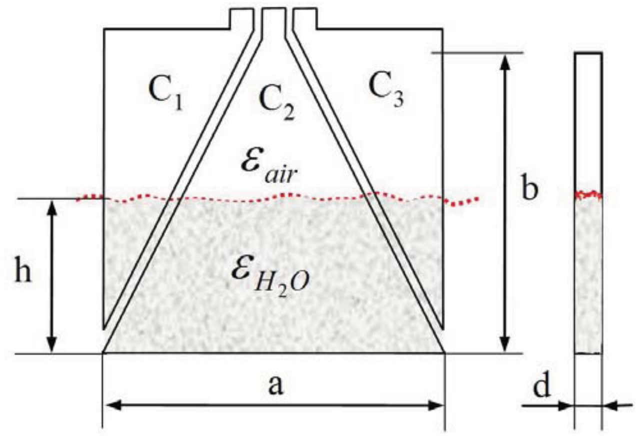

Figure 4. Top and side view of the triangular capacitive sensors.

In order to obtain the characteristic curve for the flat sensor of Fig. 1, it is placed vertically into a water container. At first, the capacitor is completely dry, that is, the dielectric is air with no humidity in the plates. Under these conditions, the water level starts to rise and thus the sensor presents the curve of Fig. 5. In this graphic, when the sensor reaches saturation and the level starts to reduce, it can be observed how the capacity grows as the plates stay damp. This behavior will not occur in the next filling and emptying cycles since the capacitor is always damp. Figure 6 shows the average of data taken during the level rising and lowering processes, which are repeated 5 times. The last two curves allow to obtain the trend ones of Fig. 7 that show a repeatability of 23 pF, which in turn means a total average margin of 1.5% over the full scale. Finally, figure 8 shows the total average characteristic of the sensor, from which the height of water is given by (5) as a function of the capacity.

$$h = 0.0791 \cdot C(pF) - 4.383 \quad (\pm 0.56) \text{ mm} \quad (5)$$

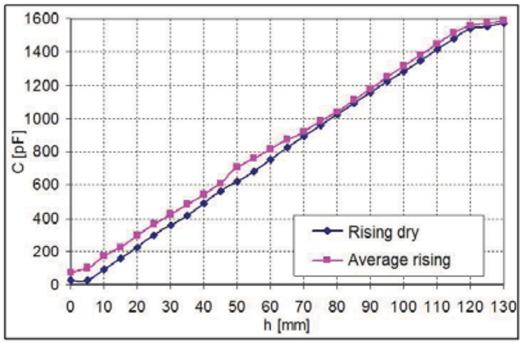

Figure 5. Response of the flat sensor of Fig. 1when initially dry.

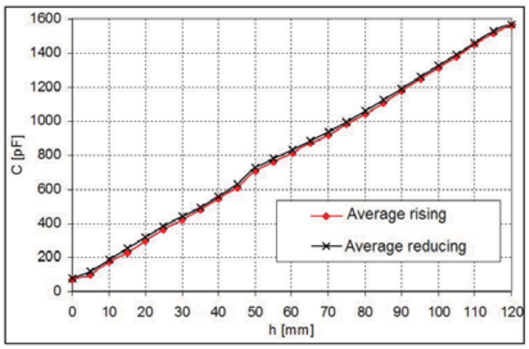

Figure 6. Response of the flat sensor of Fig. 1 with rising and lowering level after several measurement cycles.

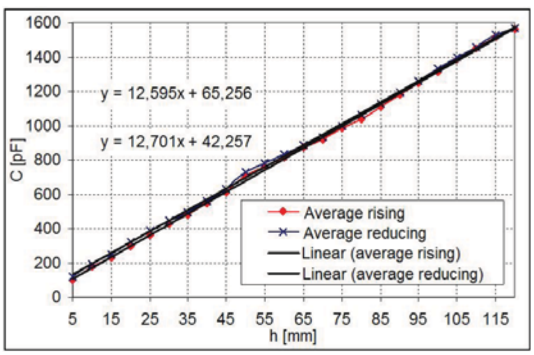

Figure 7. Trend lines for the sensor of Fig. 1 with rising and lowering level.

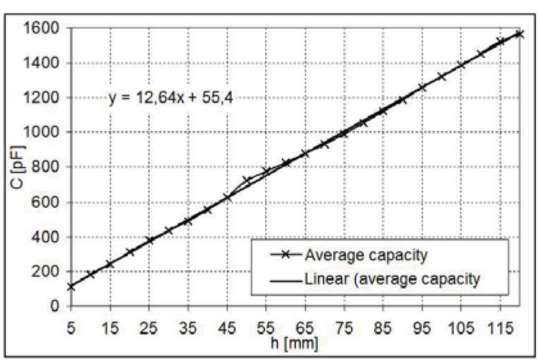

Figure 8. Total average curve and trend line for the sensor of Fig. 1.

B. Level uncertainty in flat capacitors

To calculate the uncertainty, the following parameters will be taken into account:

- The typical deviation, which is obtained after repeating the experiment five times.
- The capacity measuring resolution (1 pF).
- The length measuring resolution (1 mm).
- The following assumptions are also taken into account:
- The uncertainty introduced by the instruments has a uniform distribution.
- There is no correlation among the causes of uncertainty, that is, the SSR (Square Sum Root) method will be used to evaluate the total error.

The average typical deviation (σ) of the measurements is 9.2 pF and, in order to have a confidence margin (supposing the statistical distribution of the measurements a normal distribution) over 95%, it is assumed a value of twice the typical deviation (that is, 18.4 pF), which means an error of 1.22%. The errors introduced by the instruments are 0.04% in the capacity and 0.46% in the length measurement. According (5), the errors in capacity measurement lead to level errors, amplifying them by the curve slope, that is, 0.0791. Therefore, the total uncertainty in the level measurement will be caused by the following uncertainties:

- Uncertainty introduced in the level measurement (0.46%).
- Uncertainty introduced in the capacity measurement (0.0031%).
- Uncertainty introduced by the staff that made the measurements (0.096%).

The total uncertainty derives from these data and, according to the method utilized, it can be:

- Worst-case method. All the uncertainties are added, that is, 0.5591%.
- SSR method. They are squared added:

$$\sqrt{0.46^2 + 0.0031^2 + 0.096^2} = 0.469\%$$

C. Level measurement with cylindrical capacitor

The cylindrical capacitive sensor consists of two coaxial copper tubes, shown in Fig. 9, of 17 and 27 mm respectively. The theoretical sensor response, which is linear, is given by (6). Fig. 10 shows an image of the sensor assembling, which is about 12 cm long, inside a test tube with oil whose level will be measured. The sensor hangs from the wires connected to the capacitor plate that allow the sensor to rise and descend and thus measuring the height fluctuations of the cylinder submerged in the fluid. Sunflower oil is the fluid used in the laboratory sessions due to its low cost, for it is simple to obtain and has relatively low viscosity.

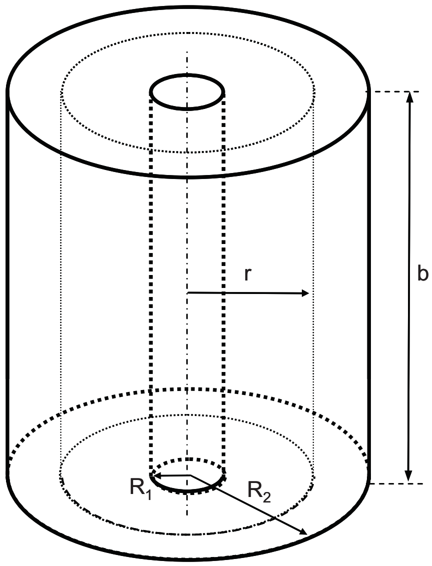

Figure 9. Cylindrical capacitor.

$$C \cong \frac{2 \cdot \pi}{\ln \frac{R_2}{R_1}} \cdot \left[h \cdot \left(\varepsilon_{liquido} - \varepsilon_{aire}\right) + b \cdot \varepsilon_{aire}\right] \quad (6)$$

Fig. 11 shows the results of the measurements made to characterize the sensor and, from Fig. 12, it can be deduced the characteristic equation (7).

$$h = 3.0506 \cdot C(pF) - 104.081 \ \ (\pm 3.54) \text{ mm} \quad (7)$$

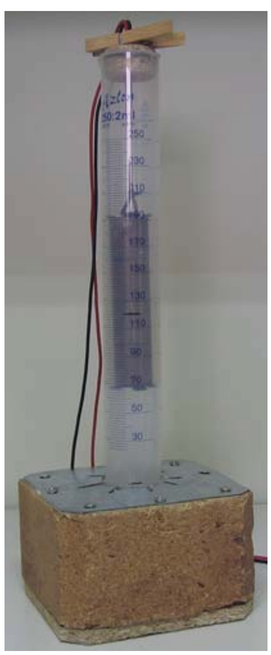

Figure 10. Photograph of the cylindrical sensor.

D. Measurement uncertainty with cylindrical capacitor

In the same way as the flat capacitors, the uncertainty is obtained for (7), which is based on applying the SSR method to the following uncertainties (8):

- Uncertainty introduced in the level measurement (0.58%).
- Uncertainty introduced in the capacity measurement (2.623%).
- Uncertainty introduced by the staff that made the measurements (2.25%).

$$\sqrt{0.58^2 + 2.623^2 + 2.25^2} = 3.54\% \quad (8)$$

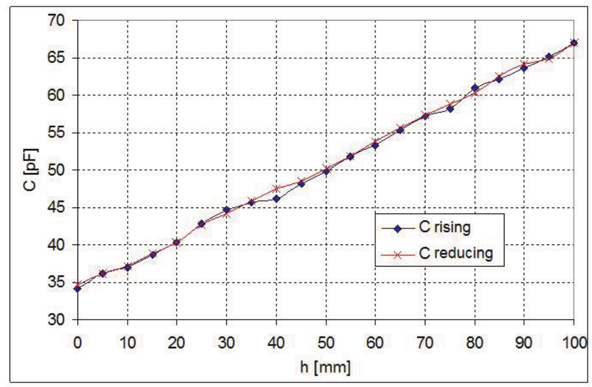

Figure 11. Response of the cylindrical sensor to level rising and lowering.

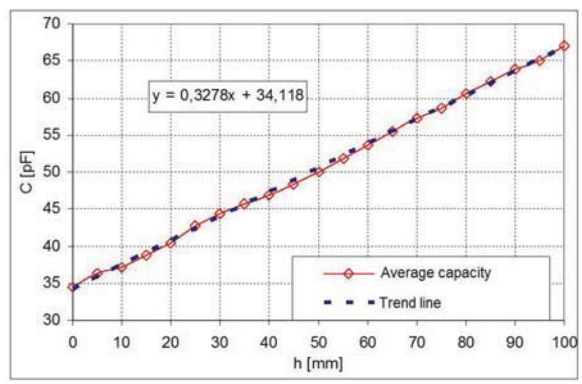

Figure 12. Total average curve and trend line of the cylindrical sensor.

III. TEACHING METHODOLOGY

The abovementioned sensors are currently utilized in the laboratory sessions of the sensor subjects given by the Electronic Technology Department of the University of Vigo. Undergraduate students of several degrees are trained in those laboratories. Among them, the degrees given by the Telecommunication Engineering and Industrial Engineering faculties stand out. This section explains the methodology followed in the subject "Laboratory of Sensors and Signal Conditioning", included in the fifth academic year of the Telecommunication Engineering degree. This subject, whose academic load is 6 credits, is given in the second term and previously, its theoretical counterpart “Sensors and Signal Conditional” is given in the first term with an academic load of 6 credits as well.

The subject is aimed at:

- Showing the student the working principle of the capacitive sensors.
- Familiarizing the student with the basics of measurement, i.e., repeatability, sensitivity, dead zone, saturation and uncertainty [7].
- Designing a complete system for signal conditioning and liquid level display in a container.

In order to achieve these objectives, the following tasks are carried out:

- Simulation of the sensor and signal conditioning circuit with PSpice [8].
- Design and assemble of the signal conditioning circuit (to be connected to a level sensor), that will be placed on a scale model.
- Acquisition of the sensor response by means of a data acquisition system (DAS), for later storage and display on a PC screen [1].

This subject has an academic load of 4 hours per week and the student devotes two sessions to carry out the work related to capacitive sensors, that is, 8 hours as a whole. In addition, the student must do, as previous homework, the design and simulation before attending the laboratory session, where they characterize the sensor, assemble the signal conditioning circuit and see the results on a PC screen.

IV. EVALUATION OF LEARNING

To assess the quality of the sensor education methodology and whether the students consider it appropriate, a survey has been elaborated and delivered to them. To this aim, the subject “Laboratory of Sensors and Signal Conditioning”, of 5th academic year of Telecommunication Engineering degree has been selected. The survey comprises 25 questions, including 16 regarding the student theoretical education in capacitive sensors, their characteristics, how to assess parameters like repeatability, sensitivity, hysteresis, linearity, uncertainty, etc. and 8 regarding the methodology followed. This one is based on low cost didactic sensors and the design of the signal conditioning system with the aid of simulation tools to finally assemble and connect to a PC.

The evaluation is carried out by the abovementioned survey, which is delivered twice to the students. The first 16 questions are delivered at the beginning of the laboratory sessions and once again at the end. The purpose of the survey is to assess how these laboratory sessions help the student acquire knowledge and understand the target concepts, which have been mentioned in the sections above. The other 8 questions are related to the interest the student has on the educational sensor applications, on the combination of design and simulation for the complete development of a measurement system and, in summary, on the methodology followed.

The surveys have been carried out during the last two academic years with a group of 8 students during 2007-08 and 19 during 2008-09. Table 1 shows the results obtained regarding sensor education and, particularly, their characterization and quantification of technical parameters.

TABLE I. RESULTS OBTAINED FROM THE SURVEYS

Academic year 07-08						
Students	8					
Questions about sensors	Total number of questions			128		
	Before			After		
	Correct Answers	Incorrect Answers	DK/NA	Correct Answers	Incorrect Answers	DK/NA
	32	62	11	87	41	0
Academic year 08-09						
Students	19					
Questions about sensors	Total number of questions			304		
	Before			After		
	Correct Answers	Incorrect Answers	DK/NA	Correct Answers	Incorrect Answers	DK/NA
	82	208	14	216	88	0

The results of Table 1 show that, with this methodology, the student acquire an important knowledge on the usage and characterization of a capacitive sensor, as well as the quantification of the technical parameters like sensitivity, uncertainty, hysteresis, etc. In the academic year 2007-08, the percentage of correct answers rose from 25 to 68% between the first and the second survey, while the DK/NA answers descended from 7 to 0%. In the academic year 2008-09 the percentage of correct answers rose from 27 to 71% between the first and the second survey, while the DK/NA answers descended from 5 to 0%.

Moreover, 8 questions were added regarding the methodology followed. This means 64 answers for the academic year 2007-08 and 152 for 2008-09. Those questions were related to the usage of simulation tools for sensors and signal conditioning circuits and the usage of educational sensors in the laboratory. The results show that 100% of the students consider the methodology very adequate for their education in this subject.

V. THE SUBJECT IN THE NEW EHEA

The European Higher Education Area (EHEA) establishes an education system based on competences and on the active role the students will have in their own learning process. Concerning sensor education, the student will acquire the following competences:

1) Specific competences:

a) Ability to specify and handle electronic instrumentation and measurement systems

2) Common competences:

a) Basic knowledge of computational tools for engineering applications.

b) Ability to use computational programs to support the development and usage of electronic applications.

c) Knowledge of basic subjects and technologies, which allow them to learn the new methods and technologies and provide them with a great versatility to adapt to the new scenarios.

d) Ability to solve problems with initiative, decision-making, creativity, and to communicate and convey knowledge, experiences and skillfulness, assuming the ethic and professional responsibility of a Telecommuni-cation Engineer.

e) Knowledge to carry out measurements, calculations, as-sessments, studies, reports, planning and similar in the sphere of activity of telecommunications.

This subject in particular presents a methodology to ease the student education, which is based upon their own work and appropriate usage of the material available, comprising didactical sensors, simulation tools and electronic components.

In summary, we strongly believe that this methodology absolutely fits in the new approach emerging from the EHEA, which is currently ongoing in all Spanish universities.

VI. CONCLUSIONS

The usage of educational sensors allows the student to see, in an easy and effective way, the operation of the primary measurement element, along with checking the sensor operation in the laboratory. Furthermore, their simplicity has contributed to unveil the sensor operation, which is often seen as a black box. It must be highlighted the benefits of the experiences carried out on studying the sensor technical characteristics like repeat-ability, sensitivity, dead zone, saturation and measurement uncertainty.

On the other hand, this methodology follows the European Higher Education Area (EHEA) and the results of the student surveys leads us to believe on its utility for the student education in sensor engineering.

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Development of a Wiimote-based gesture recognizer in a microprocessor laboratory course

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Abstract— **This gesture recognizer, developed by students in a third-year microprocessor-based laboratory course, takes Wii remote (Wiimote) as an input device to estimate the movements of the user and to compare the detected trajectory with the previously learnt movements, in order to carry out the associated actions. Such a cheap state-of-the-art wireless user interface is very attractive for the students and can be used in many interactive applications, from robotics to virtual reality and multimedia presentations. By combining commercially-available hardware, pattern-matching techniques and programming skills, we are able to foster students' interest on developing innovative potentially-marketable systems. This freeware project, implemented as a configurable publicly-available library, can be adapted to the needs of any course or student. In our laboratory this open-source DLL is used for remotely controlling a robot (based on an open-hardware Arduino platform), using a PC and the Wiimote, although the DLL can be integrated in any C, C++, Java or C# project. A GUI application (based on a Model-View-Presenter paradigm) is also provided and can be used as a template for new applications or just for debugging purposes. Although the developed application only uses data from the accelerometers, data from the infrared camera and buttons of the Wiimote is also available.**

Microprocessor; Wiimote; Project Based Learning; open source library; microprocessor programming; Arduino[1]

I. INTRODUCTION

Project Based Learning (PBL) is a systematic teaching method that engages students in learning both theoretical knowledge and practical skills through an extended inquiry process structured around complex, authentic questions and carefully designed products and tasks [1]. The 21st century information and knowledge economy is shaping the way in which colleges and universities are preparing undergraduate and graduate students with knowledge skills and abilities throughout the world. PBL is becoming one of the most important educational approaches to help faculty improve student learning process and there are many examples of its successful application in university courses [2] [3]. In university teaching it has been applied to a wide variety of disciplines from business to science [4] [5]; but most applications have been in engineering courses [6] [7]. Compared to traditional teaching, PBL technique reveals a higher degree of learning [8] [9]. PBL allows increasing students' involvement in the learning process, obtaining better results in terms of the theoretical knowledge and practical skills students are able to acquire.

In our PBL laboratory course LSED, students must face a State-of-the-art project based on a commercial Wiimote interface and R&D and innovation pattern-classification techniques.

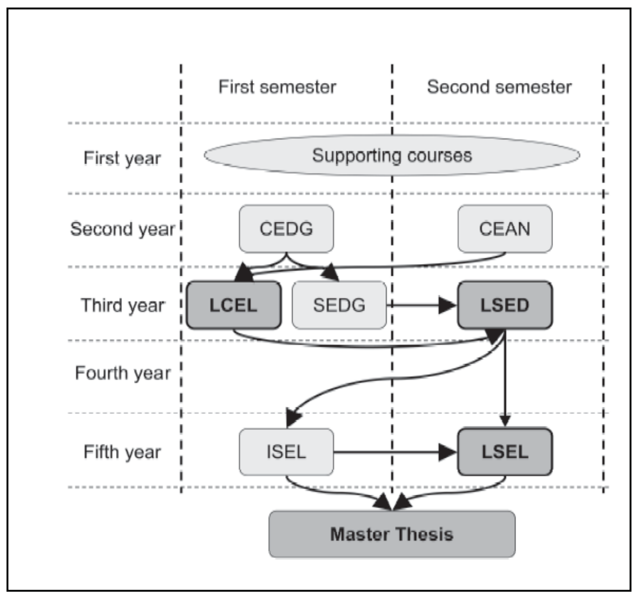

Figure 1. Structure of the curriculm on Electronics.

The paper is organized as follows: Section II describes the laboratory course in the context of the curriculum structure. The implementation of the system is described in the following sections. First the required pattern-recognition algorithms are explained; afterwards hardware and software requirements are outlined. Finally the conclusions of the proposal are drawn.

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II. Course Description: LSED

In the literature, many curriculum initiatives used PBL as their main learning strategy [4]. In some cases, PBL is enhanced using multiple case-studies or using several mini-projects for improving assessment [5]. In LSED case, students must develop a multidisciplinary supervised project.

The curriculum scheme can be seen on Figure 1. CEDG, CEAN, SEDG and ISEL are theoretical courses while LCEL, LSED and LSEL are project-based ones. The arrows show the dependencies between subjects from a theoretical point of view.

A. Theoretical courses

The three theoretical courses before LSED are problem-oriented and examination-based, with a great emphasis on analysis issues, albeit the evaluation is mainly based on the analysis of a simplified system.

CEDG (Digital Electronic Circuits) and CEAN (Analog Electronic Circuits) introduce the fundamentals of both digital and analog circuits, both in the second year (3rd and 4th semester). The gesture recognizer described in this paper can control a hardware system that can be analyzed by means of the fundamentals provided in these courses. An example (a robotic system) is described in section VI.

In SEDG (Digital Systems Based on a Microcontroller): students learn the fundamentals for programming a microcontroller-based system: inner structure, programming issues, timing resources, exception handling and peripherals (such as universal asynchronous receiver/transmitter or analog-to-digital converters). The emphasis is put on system-level programming.

After LSED, one theoretical course is left (ISEL, Electronics Systems Engineering), focused on advanced embedded systems, operating systems and real-time issues.

B. Project-Based courses

The design of electronic systems must deal with decisions in several axes:

- HW versus SW design (or co-design).
- Life cycle process: analysis, design, implementation, and testing iterations.

To involve student in dealing with all these aspects more than one semester is needed. PBL courses must be coordinated to get complementary learning objectives covering the whole life cycle and all hardware/software aspects.

In these courses, the teaching approach is based on multidisciplinary PBL, using electronics to create systems to solve problems in signal processing, communication or control areas. Students must design, build, test, and document a complete system (hardware or software or both of them) with emphasis on creativity (innovative solutions), realism (in terms of cost) and professionalism (evaluating factors such as technical writing quality and oral communication capabilities).

LCEL (Electronics Circuits Laboratory) is the PBL course that precedes LSED, focused on the design and implementation of analog and digital electronic circuits from a set of technical specifications.

LSED (Microprocessor-based Laboratory), in the first semester of the third year, students must develop an electronic system mostly based on programmable devices. The system always includes a real-time component (in the proposed Wiimote system, data from the device must be obtained and processed in an interrupt service routine), making the debugging of the system more complex and thus the development of the whole prototype more challenging.

After LSED, only one optional PBL laboratory remains: LSEL (Laboratory of Electronics Systems Engineering), focused on a software/hardware balance, reusing previously-implemented modules when implementing a fully-functional prototype. Programming is not a critical issue and the emphasis is on high-level programming and student-defined specifications.

C. Master's Thesis.

Finally, every student must complete a Master's thesis individually in order to get the Telecommunication Engineering degree. At this point, students coming from LSEL are very well prepared to take on a Master's thesis involved in one of the research and development lines developed in the Department of Electronic Engineering.

Similar to LSEL, the Master's thesis focuses on both SW and HW aspects and considers all the steps in the life cycle of the development of an electronic system.

The main difference with respect to LSEL is that Master's theses are developed individually: The student has to analyze, design, and implement the system architecture, controlling the functionality of all the modules. First of all, the student has to design a detailed testing plan, which is one of the main targets in this level of the curriculum. As a result of the Master's thesis, the student develops a quasi-professional system, generally involved in a research and development project that is being completed by the instructors with a company or a government institution.

III. Wiimote Data Sampling and End-Pointing

A sample of data received from a Wiimote is shown in Figure 6. Three different regions are shown in Figure 3.

Region 1 corresponds to a situation when no intended Wiimote movement is being made, just random movement or electronic noise is received. In this region 1, the received values vary between zero and the first threshold (green line). If an intended movement is carried out, the data values pass through an intermediate region 2, a transition area between "no detected movement" and "a movement clearly detected" (labeled in the diagram with a 2). The system detects the beginning of the movement when the data values overpass a second threshold for a brief period of time. Then, collected data is identified as a specific gesture (region 3) until data return to a noisy situation which is reached after a contiguous sequence of samples are detected below the first threshold (final region 1).

This end-pointing algorithm is implemented as a software finite state machine as shown in Figure 2.

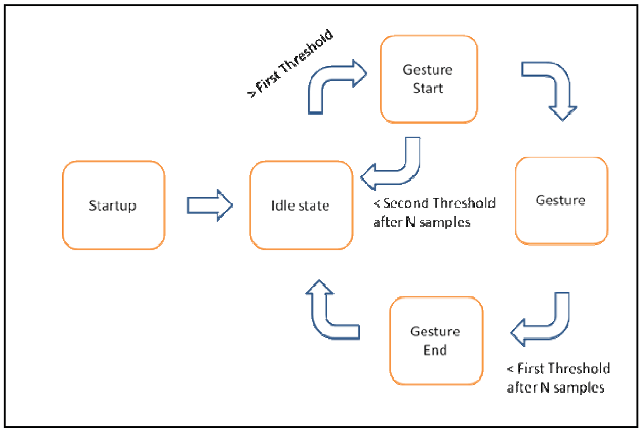

Figure 2. Finite state automaton of the gesture recognition system

The first state is Startup, which calibrates the system in order to take into account electronic noise and working conditions when establishing the values of the thresholds. This way, the system can automatically adapt to the user that is using our recognition software at that specific moment in a specific environment.

After this calibration, the Idle state starts; Wiimote data is sampled for later comparison and to know if any activity has occurred above our first threshold. If first threshold is exceeded and the system does not exceed the second one after several samples, a false alarm has occurred, no gesture should be saved and the system must go to the previous state again.

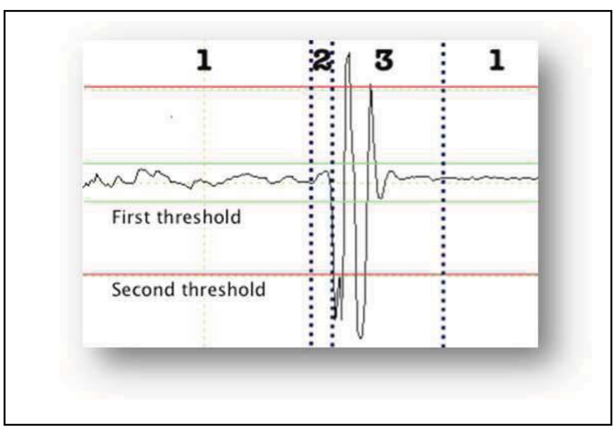

Figure 3. One-axis acceleration data when a movement is performed

If the second threshold is surpassed, a new gesture is actually being made, so the system starts to save all the data received from the Wiimote unit, until data below the first threshold is received. This involves that a new “no movement or noisy situation” has started and the movement has already finished.

IV. Gesture Recognizer System Description

In order to identify the gestures we need to have previously-collected data to compare with. That is way the recognizer works, in two modes: training mode and recognition mode.

During the training phase, end-pointed movement data is serialized and saved as an XML file. This file is used in the recognition phase to compare the new data received from the Wiimote with every movement previously saved by means of the Dynamic Time Wrapping method (DTW), very popular in the design and implementation of speech recognizers for low-end mobile phones.

This DTW algorithm is able to compare two sequences of multidimensional data (such as the three-axis acceleration data from the Wiimote) to each other, even if the length of the sequences is not the same. In order to carry out the comparison, the standard DTW algorithm allows insertions and deletions in one of the sequences (although penalizing these operations when computing the distance between the sequences) as shown in Figure 5. Although normalizing the data of the sequences (such as subtracting the average value of the sequence to each of the samples) is a usual preprocessing technique (before comparison), good gesture recognition rates have been achieved without any normalization and using a linear scale and an Euclidean distance (for other signals such as speech, it is usual to use the log-energy of the signal when computing the distance, although for acceleration data, a linear approach is completely appropriate).

V. DLL and GUI Development

The Wiimote-based gesture recognizer DLL was designed using C# Programming language on the .Net 2.0 Framework [10] [11], using a Visual Studio Express 2008 (free Student Edition) to develop the architecture, as this Integrated Development Environment is quite intuitive and easy to start working with.

Programming with this language was easy and quick thanks to MSDN Library also [14], freely available on the Internet, which collects all the documentation of the .Net Framework in a similar effective way as Java does. Thanks to the MONO development project [15], the project can be extended to other platforms based on Mac OS X or Unix systems. As future work, the team of students is in charge of extending .Net Framework to both Operating Systems.

In LSED laboratory the generated open-source DLL is used for remotely controlling a robot (based on an open-hardware Arduino platform), using a PC and the Wiimote, although the DLL can be easily integrated in any other C, C++, Java or C# project.

VI. Hardware Demonstrator

To demonstrate the capabilities of the gesture recognition system, students decided to show DLL’s functionality by controlling a small basic robot based on an Arduino Duemilanova board [16]. This board is based on Atmega328 with 16KB to 32KB of Flash memory and clock speed of 16 MHz. Its physical structure was made from various recycled plastic parts taken from old or broken devices (Figure 4.).

The main feature of this system is offering a fully open-source-based hardware platform. The available development kit is completely free and all the reference related to its programming tips can be found on Internet. The main advantage when programming an Arduino board is the use of a high-level language, very similar to C: all the libraries needed are already included in the development kit.

Figure 4. The robotic platform controled by the gesture recogniser

For demonstration purposes, students established a serial communication directly to the robot, so they could send the processed data from the recognition software in order to control the robot at will. In this case they simply recovered the data sent through the serial line and with the recovered command from the data they made the robot react in a certain way (to move forward or backwards or to turn on the left or on the right).

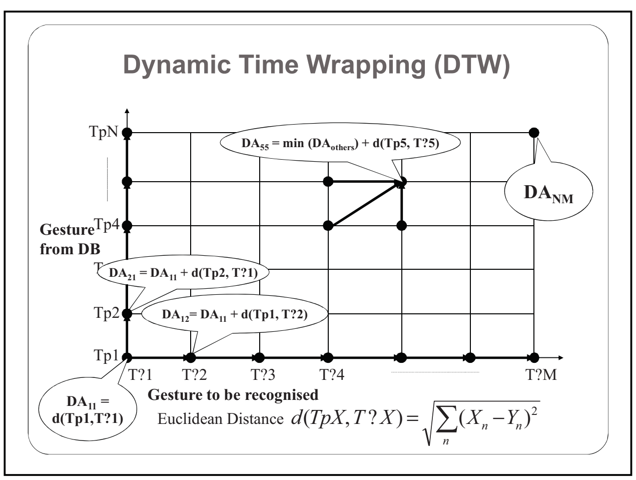

Figure 5. Graphical procedure of Dynamic Time Warping

VII. CONCLUSIONS

A new engaging project has been proposed, designed, implemented and tested for a PBL course on microprocessors. The use of cheap wireless game-oriented commercial hardware, open-source software and hardware and pattern-matching techniques is very attractive and has already engaged several teams of students during the last two years in a third-year microprocessor-based laboratory course. This freeware project is able to foster students' interest on developing innovative potentially-marketable systems.

The gesture recognizer estimates the movements of the user's Wiimote and by comparing the detected trajectory with the previously learnt movements, is able to carry out the associated actions in interactive applications (from robotics to virtual reality and multimedia presentations). Implemented as a configurable publicly-available library, it can be adapted to the needs of any course or student. In LSED laboratory at UPM, this open-source DLL is used for remotely-controlling a robot using a PC and a Wiimote. The developed DLL can be integrated in any C, C++, Java or C# project and a GUI application is also provided as a template for new applications or just for debugging purposes. Although the developed application only takes data from the accelerometers, data from the infrared camera and the Wiimote buttons is also available.

From a personal point of view, on behalf from the authors; the development of this kind of project based on the PBL methodology has been a quite profiting experience for both the students and the professor, although working with a different development environment and platform can imply an extra effort for the people involved, due to the fact that learning how to handle the different required tools takes time.

On the other hand, conducting an innovative and different project has increased people's awareness for this type of approaches. With this type of methodology we are capable of reaching others students and professors related with similar projects.

After this second-year experience, next year we can offer a standardized project to most of the students in the LSED laboratory course. There is a video demonstration at http://www.youtube.com/watch?v=joo3G3BejwY.

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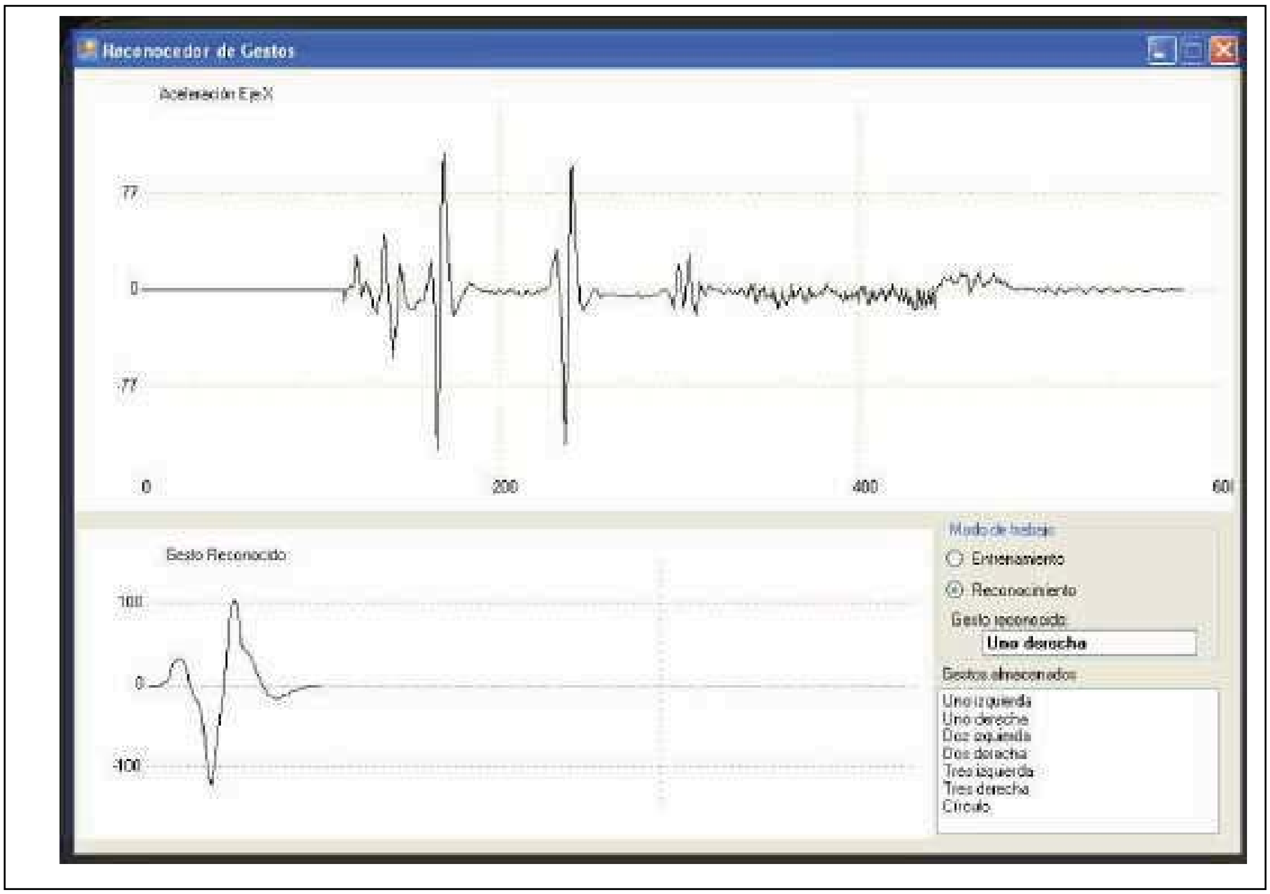

Figure 6. Graphical user interface of the developed gesture recognition system

Hands-on intelligent mobile robot laboratory with support from the industry

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Abstract—**The widespread use of robots in many areas makes the fundamental understanding of them a necessity for many electronic system design engineers. Therefore, to effectively speed up the learning process, the applications of learning-by-doing hands-on laboratory to help students get acquainted with the design and implementation of robots is inevitable. Lunghwa University has teamed up with local microcontroller manufacturers to redesign course contents, to host free workshops supported by the Ministry of Education, and to hold national contests for intelligent mobile robots. The devised low cost educational robot kits and multimedia lecture notes not only reinforce the hands-on laboratory exercises, but also help motivate students to learn actively the intelligent mobile robots.**

Keywords- mobile robots, hands-on laboratory

I. Introduction

Robots are attracting more and more people's attention recently, especially when Sony and iRobot announced the biped humanoid QRIO robot and Roomba vacuum cleaning robot, respectively. Robots are mechatronic engineering products, capable of acting autonomously in various physical environments. The widespread use of robots in many areas makes the fundamental understanding of them a necessity for many electronic system design engineers. Unfortunately, learning the design philosophy of robots is interesting but difficult, because it includes many areas of knowledge, e.g., the mechanics and electronics, linear and nonlinear vehicle control theory, and firmware programming of microcontrollers, etc. Teaching the autonomous mobile robot design course is a challenging undertaking because one can not assume that all students enrolled in the class have solid prerequisite knowledge in so many areas. It is noted by Heer *et al* [1] that introducing a platform for learning™ robotics courses enhances students' sense of community, innovation capabilities, and troubleshooting skills. The students could experience first-hand the fun associated with robots while gaining a sense of accomplishment. Therefore, to effectively inspire students' interest and motivate them to participate actively in the learning process, the application of hands-on laboratory which leads to an interesting robot to help students learn the design and implementation skills of robots is inevitable.

Heer *et al* [1] propose a low cost and easy to control Tekbots platform for hands-on freshman and even senior level robotic exercises. The Tekbots platform is simple and good for motivating the students, but it may not be used to experience more advanced firmware implementations, control, signal processing, and path planning algorithms. Kuc *et al* [2] used Javascript simulations to make students familiar with what robots can do to interact with environments. The students can develop their own logic circuit designs to program a robot for tasks of increasing complexity. Once the designs are verified in simulations, they can be downloaded to the robot and control the robot in an actual environment. Although students can check quickly whether their ideas work or not for tasks, this approach limits what students can learn in the hands-on exercises because the robot brain is a combinational logic circuit. To make the learning platform more fun and versatile, Lunghwa University of Science and Technology has teamed up with local microcontroller companies (see figure 1) to design low cost line following robots and micromouse, and the corresponding multimedia lecture notes. These companies support not only free samples of microcontrollers, integrated design environments (IDEs), but also free workshops and technical support in this project. By using a similar idea to that described by Hussmann *et al* [3] to inspire students' interest furthermore, the team also works together to hold contests for these mobile robots. The contests and free workshops for university and vocational high school students are also supported by the Ministry of Education. It should be noted that the contest[4] did attract many students and teachers. More than 200 teams compete with each other for the championships of fastest line following robots and micromouse this year.

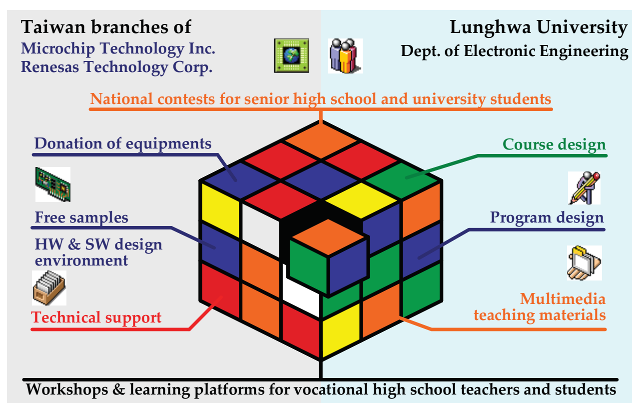


Fig. 1 The joint effort between Lunghwa University of Science and Technology and microcontroller manufacturers

II. Joint Efforts on Developing Learning Platforms

Learning by doing is a very effective idea for students to acquire knowledge, if they are well motivated. It is found that students will be willing to do tedious research work to solve practical problems when these problems are related to an interesting, and competitive contest [3]. Racing contests of line following robots and micromouse are such examples [4-5]. This is why Lunghwa University of Science and Technology wants to team up with local microcontroller companies to design low cost line following robots and micromice, and to hold jointly the corresponding contests. The followings are brief descriptions of the devised mobile robots.

A. Line following robots

Line-following robots are self operating robots that move along a line on the floor. Recently, the Fortune Institute of Technology had held 6 times of line following robot racing contests to encourage students from technological and vocational education system in Taiwan to show their creativity and techniques. It is a very successful contest not only because of the high prize, but also in attracting senior high school students to join the contest. The Taiwan micromouse and intelligent robot contest even include the line following robot racing contest as one of its major events this year [4].

The rules [4-5] allow contestants to memorize where straight lines and curve turns are along the track by providing prompts every time the curvature of the track changes. Figure 2 shows the 4th generation learning platform for line following robots of the joint effort. The idea [6] of using analog outputs of reflective optical sensors to estimate accurately the line position is applied in this prototype of learning platform. To calculate precisely the distance that the robot moves and lower down the cost, home-made encoders are installed onto two DC motors. The resolution is about 0.5mm/pulse. Two dsPIC microcontrollers are used in this configuration. One is for collecting the encoder pulse information for two dc servo motors, and the other is in charge of reading the reflective optical sensor outputs, calibrating these outputs, estimating the line position, and controlling the run speed and orientation of the robot. It is capable of running at speed more than 2m/sec. The robot costs about $ 150 USD. Two-third of the money is for the maxon DC motors due to its high performance and small size.

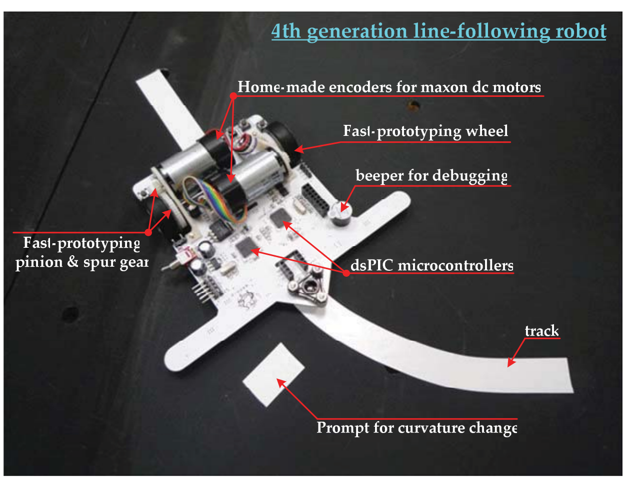


Fig. 2 A sample learning platform for line-following robots

B. Micromouse

Micromouse contests are for miniature autonomous robots to compete for the title of best speed and intelligence in solving a maze and finding the goal. Over the years, the micromouse contest became one of the few student competitions among engineering schools around the world. After all these years of development, the micromouse has made a great improvement in both maze-solving algorithms, and motion control implementation in the international competitions. This is partly due to the fast development of microcontrollers and sensors, which not only shrinks the hardware circuits, but also makes detect the environment conditions and motion control of the micromouse easier and execute the algorithms faster. These contests are still very popular to engineering students in UK [7], USA [8], Japan [5], Singapore [9], and Taiwan [4], because the micromouse project is helpful and fun for students to learn and integrate multidisciplinary knowledge. The micromouse is also a very good example for learning embedded control systems.

Figure 3 shows the 4th generation learning platform for micromouse contests of the joint effort. Local industries also contribute to make the maze court, the post, and the wall. The cost for the maze is about 30% of the price found on the Internet [10]. The functions of the two micro-controllers installed on the micromouse in figure 3 are basically the same as those for the line following robot in figure 2. Therefore, students familiar with controlling the line following robot in figure 2 can easily switch to this micromouse learning platform.

The differences between the micromouse and the line following robot that make the micromouse a more advanced project for intelligent mobile robots are threefold. They are 1) a maze-solving algorithm which should be integrated with the motion control algorithm, 2) various maze wall configurations should be taken into account in the motion control algorithm such that the micromouse won't hit the maze wall, 3) a gyro sensor should be used because the centrifugal force is large at high speed.

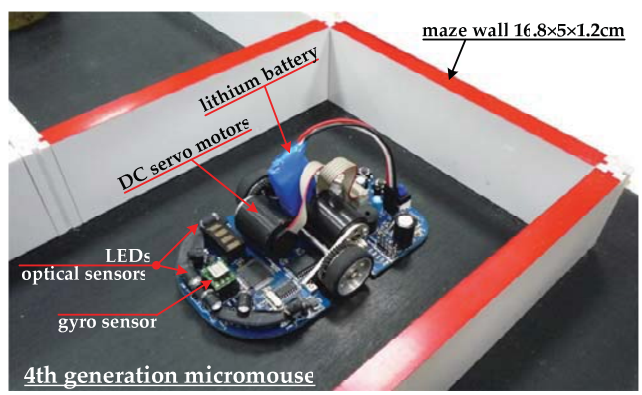


Fig. 3 A sample learning platform for micromouse contests

III. PROBLEMS STUDENTS CAN LEARN TO SOLVE IN THE LEARNING PLATFORMS

The followings are brief descriptions of some problems students may face in making their own line following robot and micromouse projects.

A. Mechanical Design of robots

Students that enrolled in department of electronic engineering in general do not have the opportunity to design their own mechanical systems. When students want to make their own line following robot or micromouse faster, they have to take into consideration the power, torque, and top speed ratings of their DC motors, the grip force between tyre and the ground, and the height of the center of gravity. These things are all related to the mobility of the robot. This motivates the students to learn computer aided software to help them design and verify their own mechanical structures before construction. Figure 4 shows such examples for mechanical designs of stepper motor and dc servo motor micromice. Although these are only simple structures and won't take students too much time to learn to design their own, they do bring a lot of fun to students in designing their own robots.

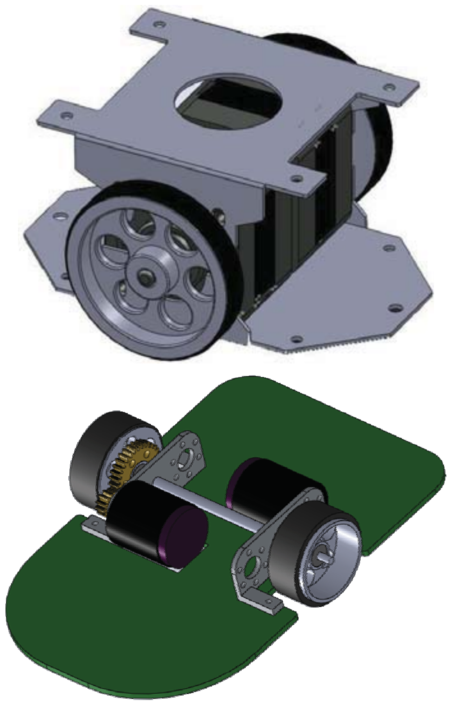
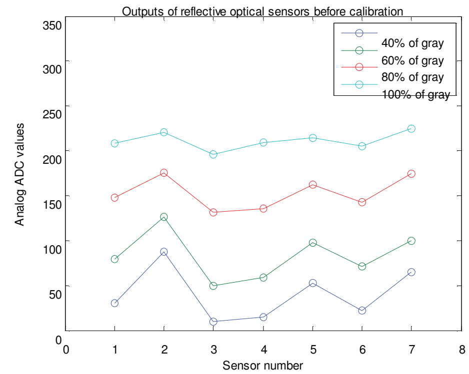


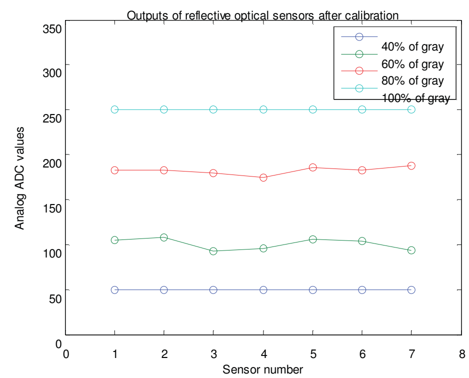
Fig. 4 Example student designs of mechanical structures for micromice

B. Calibration of Optical Sensor Outputs and line detection

To detect the line in the racing track, most people use two or more reflective optical sensors[11]. Unfortunately, this approach works fine only at low speed. Chan [6] uses analog output voltages from reflective optical sensors and digital PD control algorithms, such that the line following robot can run faster than 80cm/sec. Before students can use the analog sensor outputs to estimate line positions, each output should be calibrated to give almost the same level of voltage under the same working condition. This is due to the variations of optical sensor characteristics, even though their part numbers are the same. It can be seen in figure 5a that the output values of different reflective optical sensors vary a lot even if they are under the same working condition. Figure 5b shows the results after the software calibration procedure [12] is applied.



(a)



(b)

Fig. 5 The reflective optical sensor outputs for different gray scale (a) before and (b) after calibration

After the calibration procedure is finished, it is ready to calculate the line position based on those adjusted analog output values from the corresponding reflective optical sensor circuits. Students can use various interpolation techniques or the way of find the "center of mass" [14] to do it. It is important at this part for students to figure out a way to verify how accurate their estimation algorithm is.

Suppose that the coordinate of the 7 reflective optical sensors are x_0, x_1, x_2, x_3, x_4, x_5, x_6, respectively, and the corresponding analog output values are y_0, y_1, y_2, y_3, y_4, y_5, y_6, which is shown in figure 7. The estimated line position can then be calculated by the following weighted average formula:

$$x = \frac{\sum_{i=0}^{7} x_i y_i}{\sum_{i=0}^{7} y_i} = \frac{3(y_6 - y_0) + 2(y_5 - y_1) + (y_4 - y_2)}{\sum_{i=0}^{7} y_i}, \quad (1)$$

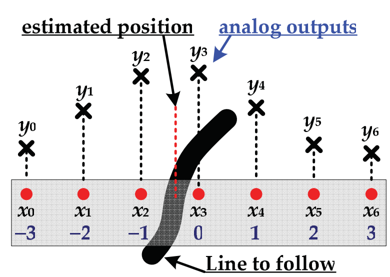


Figure 6 The line detection algorithm via weighted average

Figure 7 shows the experimental results by using the "center of mass" approach.

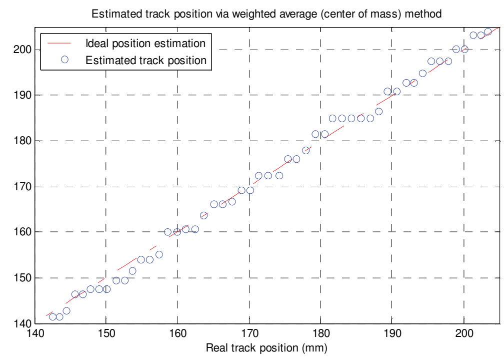
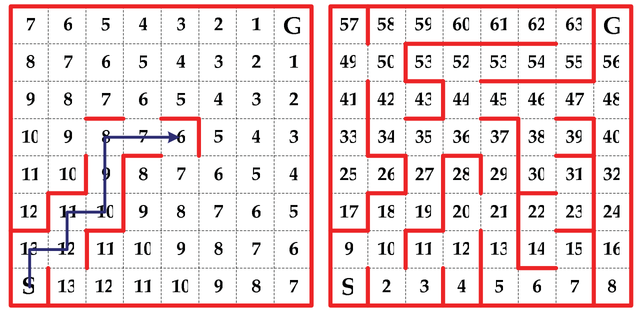


Figure 7 The experimental verification of the center of mass line detection algorithm

C. Maze solving algorithms

To solve a maze and plan a shortest path from the start point to the goal, the micromouse has to search and memorize the environment first, and then find the shortest path based on some optimization approaches. The simplest method available to a micromouse is some variation on the flood-fill or Bellman algorithm [15-16]. The idea is to start at the goal square and fill the maze with values which represent the distance from each square in the maze to the start or goal square. When the flooding reaches the goal, or start square, the algorithm can then be stopped. The micromouse could follow the values downhill or uphill to the goal square. Take the 8×8 maze shown in figure 8a as an example. The number at each square in the maze in figure 8b is the index for the square stored in the array. At first, the micromouse does not know any information about the maze configuration, except the start square. The first iteration of the flood algorithm then gives the result shown in figure 8a, if the distance value is to the goal square. The micromouse then tries to follow the values downhill to the goal square. Since the distance value to the goal square of the start square is '14', the micromouse will try to move itself to a square whose distance value is '13'. Because the square no. 2 is blocked by a maze wall, the micromouse goes from the start square to the square no. 9. The process goes on and on until the micromouse reaches the square no. 37 whose distance value is '6' as shown in figure 1a, because the micromouse can not find a way to go to squares whose distance value is '5'. Under this condition, the flood algorithm should be executed once again. The distance values in that array would be updated according to the updated maze wall information shown in figure 8a. By using the procedure described above, the goal square would be found at last.

A more advanced flood algorithm should take not only the distance between the start square and the goal square into account, but also the movement of 'going straight' or 'turning'. In other words, the time for the micromouse to move from one square to another should also be considered in an advanced flood algorithm. It is because the weight transfer effect [18] would make the micromouse skid if it makes turns too fast. Therefore the speed of the micromouse should be slower in making turns than in going straight. The above idea of using different weights on the distance recorded in each square to the goal square may also reduce possible paths after the flood algorithm is executed.



(a) (b)

Figure 8 (a) Solving the maze via the flood algorithm if the distance recorded in each cell is the distance to the goal square, (b) square indices of the maze.

When the goal square and the shortest paths from the start square to the goal square are found, the shortest paths can be furthermore optimized such that the micromouse can run in diagonal instead of consecutive 90 degree turns to reduce even more the run time from the start square to the goal square. Figure 9 shows such 3 possible paths with diagonal routes and 45 degree turns.

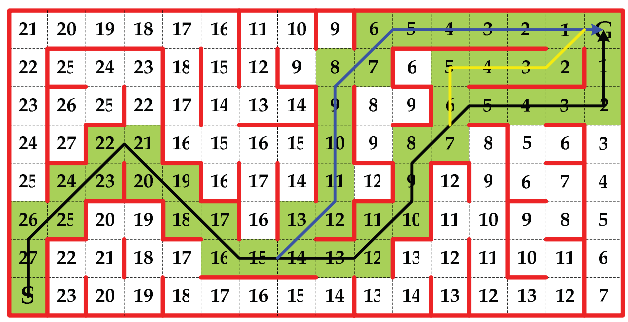


Figure 9 Using diagonal runs to optimize given shortest paths

To speed up the learning process, the maze solving algorithms described above are implemented as a simulation program which is shouwn in figure 10. The input information for maze solving algorithms is the maze wall configurations. The algorithms will then generated distance values from any square in the maze to the goal square. These values will then be used to find out the optimal route for a micromouse to go from the start square to the goal square. The user interface shown in figure 10 is convenient for students not only to define various mazes, but also to debug their codes for the algorithms.

C. Motion control algorithms

The results of the maze solving algorithm can then be used in the motion control algorithm to drive the micromouse as fast as possible from the start point to the goal. Although the optimal path with diagonal segments can be drawn by using lines (see figure 9), the trajectory for the micromouse should be smooth enough such that it won't skid due to centrifugal force when making turns.

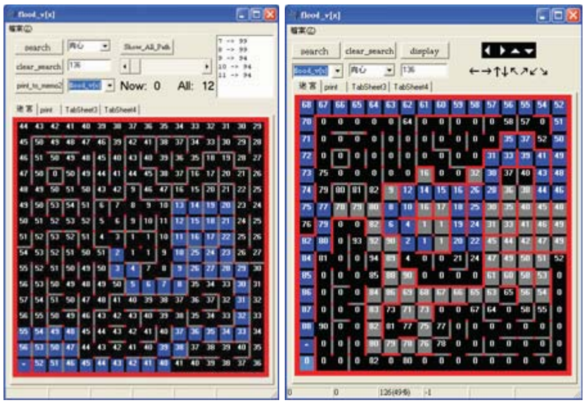


Figure 10 User interface of the maze-solving program

Therefore, smooth trajectory patterns for the micromouse when making 45, 90, 135 degree turns, and making U and V turns shown in figure 11 should be stored in the firmware of the micromouse. The stored information for these smooth trajectories includes the diameter of wheels, start and end positions, and the speed profiles for both wheels. The diameter of the wheel is necessary because the firmware can only track the steps of motors, and the distance traveled is also related to the diameter of wheels.

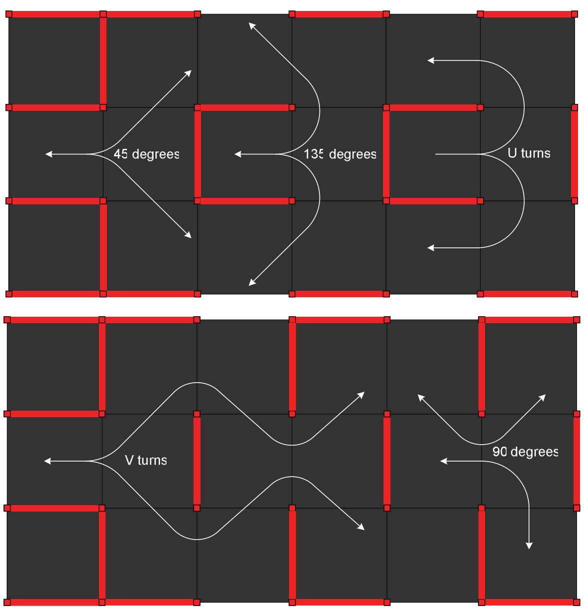


Figure 11 Smooth trajectory patterns for micromouse to make 45, 90, 135 degree, U and V turns.

The approximate mathematical equations proposed in [17] can be applied to find out the position of the micromouse in the maze:

$$v_L(k) = \pi D \times \frac{p_L(k)}{T_s \times p_C},\ v_R(k) = \pi D \times \frac{p_R(k)}{T_s \times p_C}, \quad (2.a)$$

$$v(k) = \frac{v_L(k) + v_R(k)}{2},\ \omega(k) = \frac{v_R(k) - v_L(k)}{L}, \quad (2.b)$$

$$x(k+1) = x(k) + T_s v \cos(\theta(k)), \quad (2.c)$$

$$y(k+1) = y(k) + T_s v \sin(\theta(k)), \quad (2.d)$$

$$\theta(k+1) = \theta(k) + T_s \omega(k+1), \quad (2.e)$$

where D, $p_L(k)$, $p_R(k)$, p_C, $v(k)$, $v_L(k)$, $v_R(k)$, $\omega(k)$, L, $x(k)$, $y(k)$, $\theta(k)$, and T_s stand for the diameter of the wheel, the pulse counts of left wheel at the kth sampling interval, the pulse counts of right wheel at the kth sampling interval, the pulse counts of the stepper motor to run a round, the velocity of the micromouse at the kth sampling interval, the velocity of left wheel, the velocity of the right wheel, the angular velocity of the micromouse, the distance between the wheels, the x, y coordinate of the midpoint between the wheels, the orientation angle of the micromouse, and the sampling interval for the digital control algorithm, respectively. The formula in (2) is accurate enough if the sampling interval is sufficiently small.

Although stepper motors are used in the micromouse proposed in this paper, the same pulse commands for the two stepper motors can not guarantee that the micromouse will go in a straight line. This is because the load conditions and the friction forces for the two wheels are eventually not the same. Moreover, the 45, 90, 135, 180 degree turns based on the pulse commands, circumferences of the wheels, and the distance between the wheels also need to be corrected due to measurement errors. To make the micromouse run smoothly in a given maze, there are three types of errors which need to be corrected based on the optical sensors installed on the micromouse. They are 1) longitudinal error, 2) lateral error, and 3) alignment error, which are shown in figure 12.

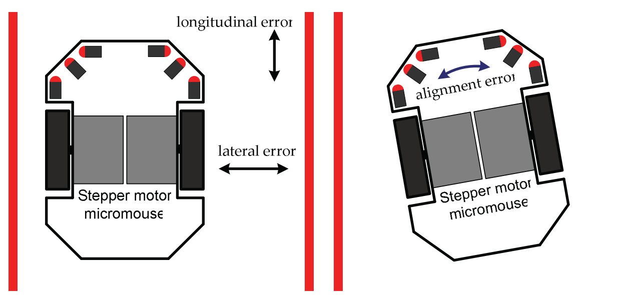


Figure 12 Error sources for a micromouse in a given maze

The alignment and lateral errors of the micromouse can be corrected by using either the pulse commands or the infrared sensor readings. The longitudinal error can be corrected if the pole position of the maze can be detected when the micromouse runs in a given maze. This is shown in figure 13. Because the initial position and the orientation angle θ of the micromouse are all set to 0, these calculation errors should also be corrected based on the infrared sensor readings. Diagonal straight line motion can be corrected by using the readings of forward-looking optical sensors, such that the micromouse would not hit the posts or corners alongside the path.

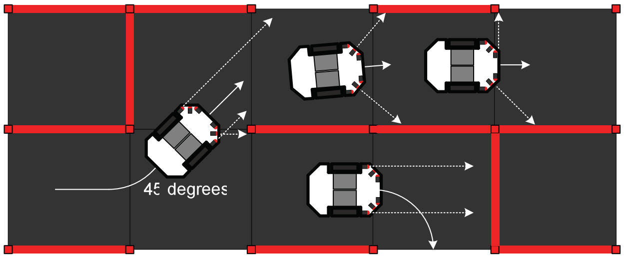


Figure 13 The strategies that a micromouse can use in correcting the longitudinal, lateral, and alignment errors

D. Workshops for vocational high school teachers and students

The joint effort described in this paper is also used to encourage vocational high school teachers and students to learn implementation skills of intelligent mobile robots. Figure 14 shows the free workshops financially supported by Ministry of Education. Lecturers include students, teachers of Lunghwa University of Science and Technology, and technicians from local microcontroller manufacturers. Although most of the students are teaching assistants, there are indeed some students who are proficient enough acting as lecturers. Moreover, every one of them who joins the workshop can bring back not only the intelligent mobile robots, but also the IDEs.

(a)

(b)

Figure 14 Free workshops of (a) line-following robots, and (b) micromouse for vocational high school students

IV. CONTESTS FOR INTELLIGENT MOBILE ROBOTS

To see how well students integrate all the skills learned in the hands on laboratory in implementing line-following robots and micromice, contests (see figure 15) were held after they finished their intelligent mobile robots. Students are also encouraged to join national contests [4]. It is interesting to note that the racing contest did motivate the students to strive to learn the knowledge and skills necessary to make intelligent mobile robots. For example, one group of students in line following robots tried changing the distance between consecutive optical sensors and obtained better results in predicting the line position. They even made a new line-following robot (shown in figure 16) which could run at a maximum speed of 1.2m/s. This is a competitive design to those devised by Cook [13].

(a)

(b)

Figure 15 Contests for (a) line-following robots, and (b) micromouse.

V. QUESTIONNAIRE FEEDBACK

A survey was conducted in a hands-on laboratory for line following robots. It can be seen from Table 1 that the feedback on the questionnaires from the students was quite positive. The majority of the students (78%) agreed that they were motivated to learn those skills and theories, and were satisfied (90%) with the organization of the laboratory. The feedback also shows that the project-based laboratory was more appealing than an earlier conventional laboratory. However, there are three students who thought that the cost is still too high for them, which is partly due to the fact that most of the department's students are economically disadvantaged.

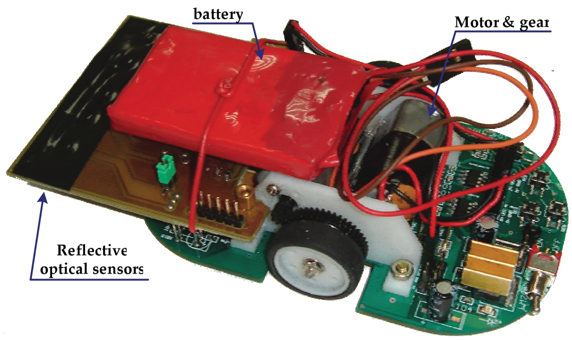


Figure 16 The new line-following robot devised by students

Table 1. The average scores of the survey for the hands-on laboratory

Questions	Average
The hands-on laboratory can effectively help me learn hardware circuit and programming implementation skills.	**4.06 (1-5)**
The contests held after the mobile robots are finished interest me a lot and encourage me to learn more about the necessary skills and theories.	**3.91 (1-5)**
It is more interesting to me to make the robot from scratch in both hardware and software, because each step is explained in detail.	**4.15 (1-5)**
I am willing to pay the money to own the mobile robot.	**3.52 (1-5)**
I am satisfied with the project-based hands-on laboratory.	**4.50 (1-5)**

VI. CONCLUSIONS

The joint effort of Lunghwa University and local microcontroller manufacturers to redesign course contents and learning platforms, to host free workshops for vocational high school teachers and students, and to hold national contests for intelligent mobile robots are described in this paper. The effort was also appreciated and financially supported by the Ministry of Education. The local microcontroller manufacturers support not only free chips and IDEs, but also technicians to help teach in workshops. The effort is seen to effectively motivate students in classes and workshops to learn actively the intelligent mobile robots.

ACKNOWLEDGMENT(S)

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Cybertech: Robotic Competition and Subject

Learning Mechatronics from a practical point of view

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Abstract—**This paper describes a subject and contest held in Universidad Politécnica de Madrid. This contest offers the students the opportunity of developing one or more robots so they can put into practice all their knowledge on electronic and mechanical systems. As a subject, all the students can attend a course in which they learn the basics on mobile robots. As a contest, it encourages all participants to improve their designs so they can win important prizes.**

Cybertech; robot; contest; subject; bull; fighting

I. INTRODUCTION

Robotic Competitions for undergraduate students are very popular nowadays. It has been demonstrated that this is a good method to involve the students in working teams and a way of teaching how real components work [1][2][3].

There are different contests all around the world where students develop different kind of robots for educational purposes, like Fire-Fighting [4], Robocup Junior [5] or Hispabot [6]. But other competitions are focused on reinforcing the research efforts on different areas, like RoboCup Soccer Competition [7] and RoboCup Rescue [8].

All these competitions have something in common, the participants must show a working robot which can perform the task and they compete with the others to demonstrate that their prototype is the best. This makes the participants try to do their best and consequently the results are better.

The Universidad Politécnica de Madrid has several engineering competitions, one of them is Cybertech. The Cybertech competition started on 2001 with only 96 students and has increased this amount until 2008 with 140 students. Cybertech is yearly held at Industrial Engineer Faculty. Any UPM student can participate in the contest and attend the subject, no matter what faculty he/she is studying at.

Cybertech is a contest and subject made for and by students. It is coordinated by one professor at the Industrial Engineer Faculty and organized by last year undergraduate students and postgraduate students.

The students are grouped into teams of four or five people to design and build one or various robots. They can decide what event they are going to take part. Participants also have to prepare an oral presentation of their projects.

There are several challenges in Cybertech: Line-Followers, Maze, Bull-Fighting, Solar Racers and RoboSim. These challenges are widely explained in section 2.

The competition usually takes places around April. Section 3 shows how the contest is organized.

The contest is also an elective subject for the UPM students. This subject represents six free election ECTS credits. The subject is related on section 4.

On section 5, there is a description of the material given and recommended to the participants. Teams with students registered in the subject are given the Arduino microcontroller so they can follow the coursework.

Section 6 shows the amount of participants in each Cybertech edition and the influence of different milestones in the number of students.

Last section explains some improvements for the upcoming years in the contest and subject.

II. THE CHALLENGES

A. Line-Followers

The most popular event in Cybertech is the line-followers. For this event, participants must build a robot that follows a black line over a white background.

This event has several difficulties in the robot's path. First

Figure 1. Line Followers Track.

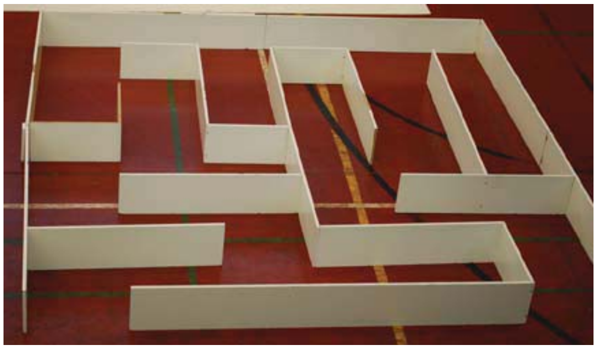

Figure 2. Maze.

of all, the robots must be capable of turning corners, which means in most cases that the sensors will lose the path. In second place, there are forks where the shortest path is marked so the robots can decide to take this way instead of the longer one.

The contest consists of three different trials. First of all, participants compete against each other trying to take as little time as possible to complete a path. There are two symmetric paths so participants can play two at a time.

The second trial is based on car races. This time four or more participants, depending on the amount of them, compete at the same time in a track with two parallel paths as seen in Fig. 1. The robots must be capable of overtaking one each other in case of collision. The semifinal and final trials bring the best participants face to face in a track similar to the previous one but with fixed obstacles they must overtake.

B. Maze

In this case, participants must do a robot capable of solving a maze. These robots usually are the smaller ones and use distance sensors to detect the walls.

The maze, as seen on Fig. 2, is made of white wood and can be changed by the organization.

In the first trial, participants know the maze map one day before the contest. In this case, they can think what the best

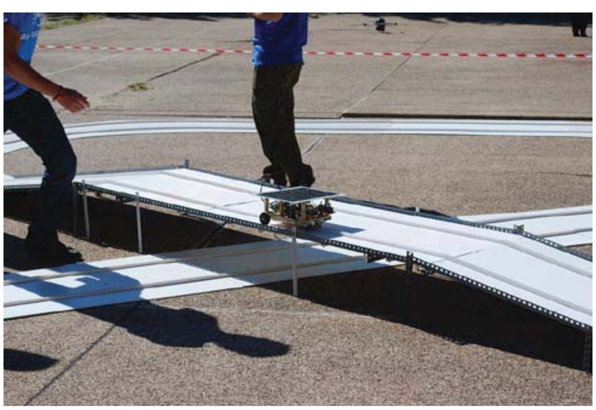

Figure 3. Solar Track

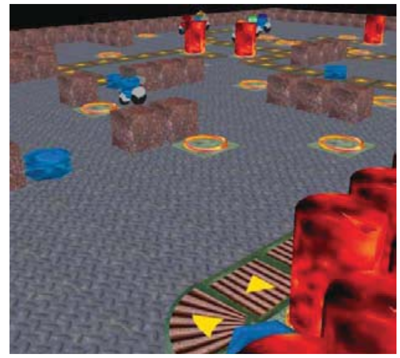

Figure 4. RoboSim Maze

strategy to solve the maze is.

Next trial's plane is given once the first trial is finished so they have little time to prepare their robots.

In the final, participants don't know how the maze is, so the robots must take their own decisions. These kinds of trials makes it unadvisable to program the map in the robot so it knows the maze. Participants usually have to research in common ways of solving mazes, which is an important part of the subject.

C. Solar Racers

One of the most important things that an engineer must take into account is that it is essential to know and improve new sources of energy.

In this event participants must develop a car which can move only by using solar energy. The cars must be capable of going up a slope and moving under a shade (Fig. 3.), but the amount of stored energy is restricted.

For this challenge the participants mainly develop the electronic power system and the chassis with motors. The car doesn't need to turn because there's a rail in the floor so the designers can concentrate in the power problems.

D. RoboSim

In this event the robots are virtually simulated in computers and participants must develop a computer program to control the robot.

Participants' program connects to the main server where a maze is held. This program must act as a robot in the maze, where there are different kinds of challenges and obstacles like fire or slippery ground as seen on Fig. 4. In each round all participants play at the same time and the one that gets first to the target earns extra points.

E. Bull Fighting

The Bull Fighting event makes the difference between Cybertech and any other robot contests. For years, participants had to fight against a bull given by the organization [9] but this was real hard to beat.

Figure 5. Bull Fighting.

Nowadays the participants develop both the bull robot and the bullfighter in the same robot (Fig. 5.). The bull robot has two pins in the front so it can attack the bullfighter, which has a balloon around itself.

The contest is as easy as trying to survive for several minutes the bull continuous attacks. It is also appreciated that the bullfighter gets near the bull instead of running ahead. As in real bullfights, the public will show white handkerchiefs at the end and the more they show, more points will earn the bullfighter.

III. CYBERTECH AS A CONTEST

As a contest, Cybertech is open to any UPM student who wants to participate and it is not needed to attend the subject. This makes Cybertech a really interesting event for the UPM as different faculties can try to win the contest. Nowadays there are students from Industrial Engineer, Computer Science, Aeronautical Engineer, Telecommunication Engineer and even, Agronomist Engineering participating in the contest as good as the Erasmus students. The contest normally takes place on Spring and lasts for two days. During the first day most of the events are held so on the second day only the participants who attend to semifinals and finals must come. It is done this way because the contest days are common school days so the participants must attend their lectures.

A. Cybertech International Contest

On 2008 there was a Cybertech International Contest in cooperation with BEST (Board of European Students of Technology) [12]. During one week 44 students from 20 European countries prepared robots for the bullfighting event. The students were grouped in teams of four people so each member in the team had different skills. The course's last day there was a competition between the teams to determine which one had done best.

IV. CYBERTECH AS A SUBJECT

There are two kinds of participants in Cybertech: the ones who only want to participate in the contest and the ones who are registered in the subject. These latter must attend a coursework that consists of four workshops.

A. Workshops

The workshops give the student a general idea about mobile robots. Each one of them takes almost four hours. The workshops are focused on how to develop a mobile robot for one or several challenges. During these workshops the students don't develop their prototypes; this must be something they do on their own so they can use their imagination.

During the first workshop, the students are introduced into several theoretical aspects of the subject such as microcontrollers, power supplies and how to program the controller. One of the most important things the students learn during this workshop is to solder electronic elements in PCB. They have to solder a motor control board which will be used in other workshops to control DC motors and in their final prototype.

The second workshop is focused on programming the microcontroller. Most students in Cybertech have never programmed before in C language, and none of them have programmed a microcontroller. It is then compulsory to explain how they can interact with the input/output signals.

Third workshop tries to give the students an overall idea on working with digital sensors and switches as well as how to control a DC motor. They must learn some common schematics to use sensors and how to filter the rebounds on the switch signal via hardware or software.

Fourth and final workshop is meant to introduce the students in the use of analog sensors. This can be a very wide field of study so they are only told how to use a specific sensor and how to measure the analog value in the microcontroller.

B. Tutorships

Once the students complete the workshops a tutor is assigned to each team. Usually a tutor has up to five groups of people during the year. The students must talk to their tutor regularly and tell him how they make progress. The tutor must answer all the questions the team could ask and depending on their knowledge he must encourage them to research more accurate solutions to their problems. When the team is made up of second degree people it is enough for them to achieve a

Figure 6. Workshop.

Figure 7. Team presenting their prototype.

working robot, but for last degrees it is common to ask them for better prototypes.

C. Presentations

All teams including a registered student in the subject must present their work in public. The presentation can't last for more than ten minutes and they must explain the main mechanical and electronic parts of their design.

As the presentations are done months before the contest, the teams are encouraged to present their robots as the best robots ever. It is also a way to make the teams work on their designs soon before the contest and consequently there are few last time prototypes in the exams.

D. Conferences

To improve the students' knowledge on robot systems, Cybertech organizes several conferences on different subjects each year. As an example, on 2008 there were three conferences on art and the relation with robots. During the conferences, severeral people showed how they could transform old computers and mechatronics into different sculptures or music instruments. In fact, we were glad to invite Carlos Corpa who showed how he and a Computer Science professor developed the poet robot PaCo. It was on 2005 when the most recalled conference was given by the Spanish astronaut Pedro Duque, who explained how different robots worked in the space. Since then, all the conferences are strongly recommended between the students, demonstrating how people are always interested in robots.

E. Exams and grades

Prior to the contest the teams have an exam in order to verify their prototypes. These exams usually are small events as the ones in the contest in which the participants must show that their robots are good enough to participate in the real events. The final grades are calculated as seen on equation (1). The most important result is the position in the contest (C), if a team wins the any of the events they are given top marks, but it is only needed to attend to obtain five points out of ten. The exam (E) and the presentations (P) have equal weights. Finally, the tutor (T) can give different grades to each team member depending on their work.

$$G = 0.5C + 0.2E + 0.2P + 0.1T \qquad (1)$$

V. THE ROBOTS

All the robots must be autonomous and no bigger than an A4 paper sheet in area (less than 30x20 cm). It can't also weight more than five kilograms. It is absolutely forbidden to use a commercial robot in the competition, so all the robots must be hand made by the students. Fig. 8 shows several robots developed for the Line Followers Challenge.

The only exception to these rules is the bullfighters. These robots are made with a commercial base given by the organization which includes a PIC microcontroller and several distance sensors.

All teams including any student registered in the subject are given a set of material so they can attend the workshops. The following explains all the components.

A. Arduino

The microcontroller used in Cybertech is Arduino Duemilanove [10]. This controller is very cheap and enough for the purposes of the subject and contest.

To control a couple of DC motors the set includes a commercial Motor Shield [11] for Arduino Duemilanove. This shield can handle up to two DC motors. The shield is unsoldered out of the box so the students must solder all the parts in the first workshop.

B. Sensors

The students are free to choose the sensors they want to use, but the organization gives them a CNY70 which can distinguish between black and white over flat platforms. These sensors are analog sensors so they can use them to practice with analog and sensors and then they learn how to turn it into digital information with a simple inverter.

The other sensor that is recommended but not given to the

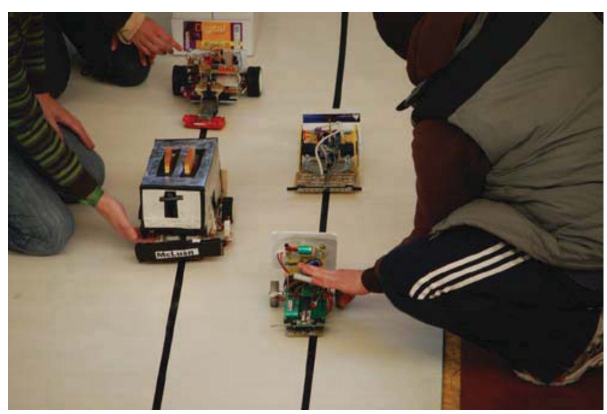

Figure 8. Line Followers Robots examples.

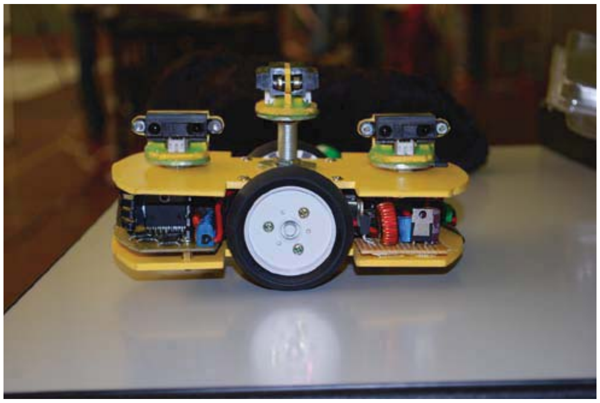

Figure 9. Robot developed for the maze event.

students is the GP2D12. This distance sensor uses IR and provides an analogical signal to measure the proximity of the objects. This can be very useful for line following participants so they can overtake without touching the opponent's car.

These sensor are widely used for the Maze event, for example, the robot shown on Fig. 9. has six distance sensors on it to detect the surrounding walls.

C. Others

The set of materials also includes different components as switches, leds, resistors and potentiometers. All this material is very useful during the lessons so the students can try different schematics and the interaction between the parts and the microcontroller.

VI. PARTICIPANTS

Since 2001Cybertech has had a lot of participants. Until 2005 there was no course related to the contest and, since then, the amount of participants has increased until 2008. The inclusion of the course resulted in the improvement of the prototypes and therefore a lot of rules had to be changed. As an example, the inclusion of obstacles in the line followers' track was done on 2006, making it impossible to win if the robots can't overtake them.

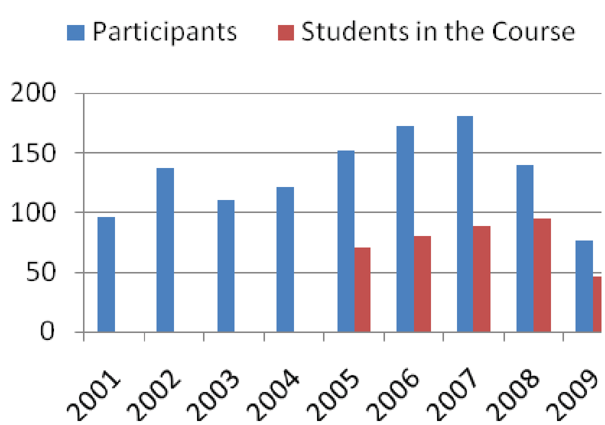

Figure 10. Number of Participant in Cybertech.

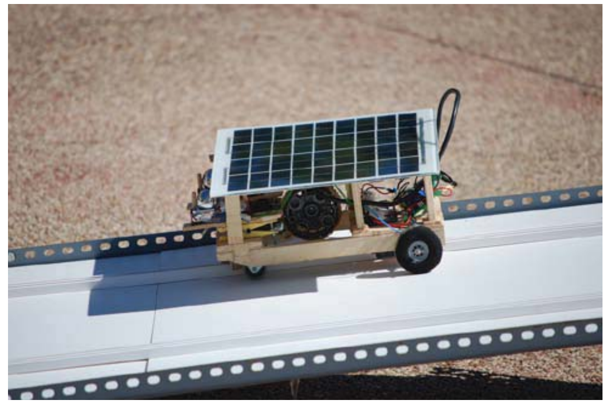

Figure 11. Solar Robot.

During 2009, for reasons beyond the organization responsibility, it was impossible to organize the contest until January so the amount of participants decreased considerably due to the few time to register.

The number of participants showed in Fig. 10 means that Cybertech is one of the most crowded subjects in Universidad Politecnica de Madrid. Every year there are more students from different faculties interested in participating and lately other universities from Spain has asked if it is possible for them to take part in the contest.

VII. UPCOMING EDITIONS

Right now Cybertech is preparing the 2010 contest and subject. On its tenth birthday the organization is willing to introduce several changes that will improve both the subject and the contest.

First of all, we are planning on an inheritance program so the teams that year after year participate in the contest will change the older members with new students. These teams are normally groups of people that registered in the subject when they were in the second degree and kept participating in the contest every year, improving their robots. It is our interest that when someone in the team refuses to participate in the next edition, the team can choose between several young applicants the new member of the group. These applicants should write a letter of motivation introducing themselves, explaining why they want to become the new team member and highlighting their skills.

On the second hand, the RoboSim event will be replaced with a Soccer League. This contest is based on the RoboCup Soccer Simulator [14] and it is intended to form groups that will be able to participate in the real RoboCup contest.

The reason why Cybertech is taking this decision is that we want it to be not only a Universidad Politecnica de Madrid contest, but a way to get to the big robot competitions that are held over the world as seen on section I.

VIII. CONCLUSIONS

Cybertech is a great opportunity for all UPM students. The participants have the chance to apply all the knowledge

Figure 12. RoboCup Soccer Simulator. [13]

acquired in their studies and to learn things that only the experience can teach.

Most of the participants undertake this kind of project for the first time in their lives and learn the importance of coordination between the team members, as good as to research solutions for real problems.

From 2010, the students that choose to participate in the Soccer League will probably have the opportunity to attend to the real RoboCup competition, as long as they prove their programs to be good enough for the contest. This is a great opportunity that will surely become Cybertech's best appeal.

Cybertech is also a chance for the students in the organization to learn several administrative tasks like how to organize a coursework. They also learn how important it is to obtain the funds needed to organize the events.

In future editions of the contest, it is possible that there will be an international event. It is the organization will to have a contest with as many foreign universities as possible participating in the bull fighter's arena.

ACKNOWLEDGEMENT

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Session 03B Area 2: E-Assessment

A new competency-based e-assessment data model
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On Education Quality Control Issues for Sino-France Hybrid Engineer Diploma
Jiang, Jin; Qian, Jinwu; Zhao, Ling
Shanghai University (China, People's Republic of)

Assessment of learning activities in discussion forums online
Nesterova, Elena; Ulloa, Ricardo
University of Guadalajara (México); University of Guadalajara (México)

SOA-based Architecture for a Generic and Flexible E-assessment System
Al-Smadi, Mohammad; Guetl, Christian
Graz University of Technology (Austria)

A new competency-based e-assessment data model

Implementing the AEEA proposal

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Abstract. **There are two unsolved problems in the field of virtual learning environments: a set of new types of assessment is required for learning management systems (LMSs), and there is a need for a way to assess lifelong adaptive competencies. Proposed solutions to these problems need to preserve the interoperability, reusability, efficiency and abstract modeling already present in LMSs. This paper introduces a competency assessment data model (CADM) being developed as part of adaptive evaluation engine architecture (AEEA). AEEA is designed to solve the above-mentioned problems while fulfilling all quality requirements. The CADM is described with a data centric model using XML for each assessment scenario.**

Keywords: Competencies, Adaptive Assessment; Competency Assessment Process; New Assessment Types; Virtual Learning Environment.

I. INTRODUCTION

IMS question and test interoperability (IMS-QTI) [1] is an open technical e-learning specification to support the interoperability of systems and the reusability of assessment resources. Items and testing can be expressed and interchanged using IMS-QTI assessment. IMS learning design (IMS-LD) [2] is a specification for a meta-language which enables the modeling of learning processes, and is designed to express many different pedagogies. The activities to develop in a learning design can be expressed with IMS-LD.

In order to support new types of assessment in an e-learning process while preserving interoperability, reusability, efficiency and abstract modeling, new models to extend the current e-assessment specifications are required. In [3] and [4] a UML model is proposed to extend and combine IMS-QTI and IMS-LD specifications. [5] - [8] show how an outcome variable of a QTI test can be coupled to an IMS-LD property, and how assessment application tools can be integrated with IMS-LD as services. [9] and [10] propose the creation of a new layer over IMS-QTI and IMS-LD data, thereby establishing a new specification by building a high-level assessment process modeling meta-language. The LAMS project [11] is another kind of proposal based on IMS-LD and IMS-QTI specifications, but a totally new specification is being built to support a whole range of possibilities in e-assessment.

The development of lifelong competencies is a global tendency that uses the e-learning process to eliminate space and time barriers. This is the background against which new pedagogical models supported by new assessment process models are needed.

These two ideas were taken into account in [12] when adaptive evaluation engine architecture (AEEA) was proposed. AEEA is a competency-based adaptive assessment process for to judge the competencies of learners in a virtual learning environment. The process is supported by extensions for educational specifications and for integral user modeling. In order to implement AEEA, four data models must be integrated: a competency data model [13] and [14], a user model [15] [16] [17] [18], a competency assessment learning design model [19], and a competency assessment data model (CADM). The design of a CADM, which includes the entire data model for e-assessment scenarios proposed in AEEA (formative peer assessment, formative teacher assessment, self assessment and summative assessment), is presented in this paper. It is described with a data centric model using XML for each assessment scenario.

The assessment items metadata and the test metadata are based primordially on the IMS-QTI specification and complemented with XML data on the appraised competencies.

The paper is structured as follows: in Section 2 the relationship between competencies and e-assessment is described. In Section 3 an AEEA overview is presented. In Section 4 a competency data model, user model and competency assessment learning design are explained. In Section 5 the new competency assessment data model is proposed. In Section 6 conclusions and proposals for future work are laid out.

II. COMPETENCIES AND E-ASSESSMENT

Competency acquisition is the process through which people engage in activities or solve everyday problems in a professional or work context, through the joint exercise of three types of knowledge: know-how, knowing how to learn and knowing how to be, accompanied by critical awareness and the taking of responsibility for actions undertaken [20].

Competencies based on a virtual learning process join theory and practice, contextualize training, guide the organization of content and activities, promote comprehensive education (the three types of knowledge) and establish mechanisms for rigorous ongoing assessment based on performance in problematic situations in the relevant context (discipline, social, scientific, etc.). To address a competency acquisition process, LMSs need to transform their learning design and assessment methods.

To carry out a competency acquisition process the traditional summative assessment provided by an LMS must be complemented with other types of assessment. Formative assessment, self assessment, peer assessment and 360-degree feedback might all be considered. This information is stored within a portfolio assessment to obtain an all-round measurement of the level of competency acquisition.

- Assessment can be considered *formative* when the feedback from learning activities is used to adapt the teaching to meet the learner's needs or to encourage students to take control of their own learning.
- *Self assessment* is where students make judgments about their own work. Students critique their work and form judgments about its strengths and weaknesses.
- *Peer assessment* is student assessment of other students' work, both formative and summative.
- In e-learning *360-degree feedback* refers to feedback that comes from all the different actors around the student. The name refers to the 360 degrees in a circle, with the student at the center of the circle. Feedback is provided by subordinates (e.g., where the student is leader of a team), peers, and teachers. It also includes self assessment and, in some cases, feedback from external sources. Fig. 1 shows the relationships between participants in 360-degree feedback in e-learning.
- *Portfolio assessment* provides evidence of the learning process as an active demonstration of knowledge. It is used to evaluate learning processes and learning outcomes, as well as to encourage student involvement in their assessment, their interaction with other students, teachers, parents and the larger community.

During a course each type of assessment produces at least one outcome variable linked with some assessed competence. The set of outcome variables allows student classification. Based on this classification, an adaptive decision is made about changing the path and resources for students in their learning design. Fig. 2 shows the proposed competency acquisition run time process

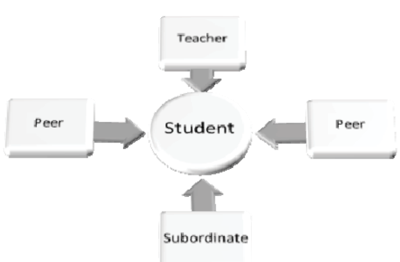

Figure 1. 360-degree feedback in e-learning

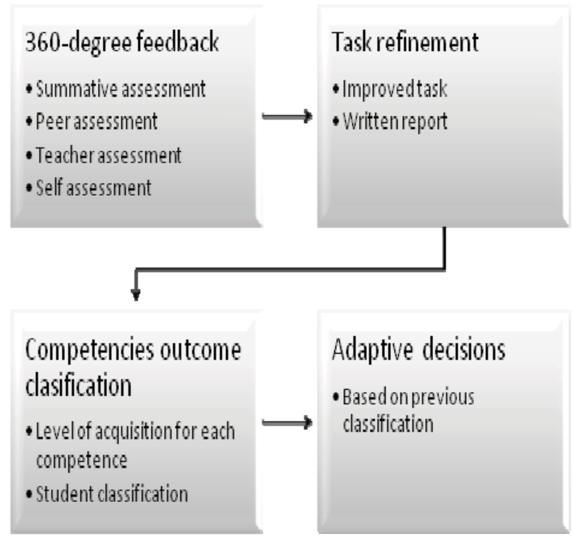

Figure 2. Competency acquisition run time process

III. AN AEEA PROPOSAL OVERVIEW

The main aims of AEEA [12] are: 1) to create an adaptive assessment structure in the learning design based on a definition of the competence element; 2) to build repositories of assessment items and tests with additional meta-information about the competencies assessed; 3) to build different, new, assessment engine software tools integrated within an LMS; and 4) to define a set of rules to drive learning design adaptations aimed at producing an adaptive competency e-assessment process.

AEEA is composed of two packages: an *Author Assessment Package* to support design time process steps and a *Monitoring Assessment Package* to support the run time process steps.

The first package proposed in AEEA, the *Author Assessment Package* (Fig. 3), covers the first three steps of an e-assessment process at the design stage:

- *Competency Assessment Plan Design*: to select the sequence of appropriate assessment types to demonstrate students' competencies; to construct and define decision rules and assessment policies for adaptation.
- *Items Construction*: to prepare items of evaluation in different assessment authoring software tools.
- *Tests Construction*: to build units of assessment for each type of assessment proposed in the assessment plan. The unit must assure the type and value of the expected response in the plan.

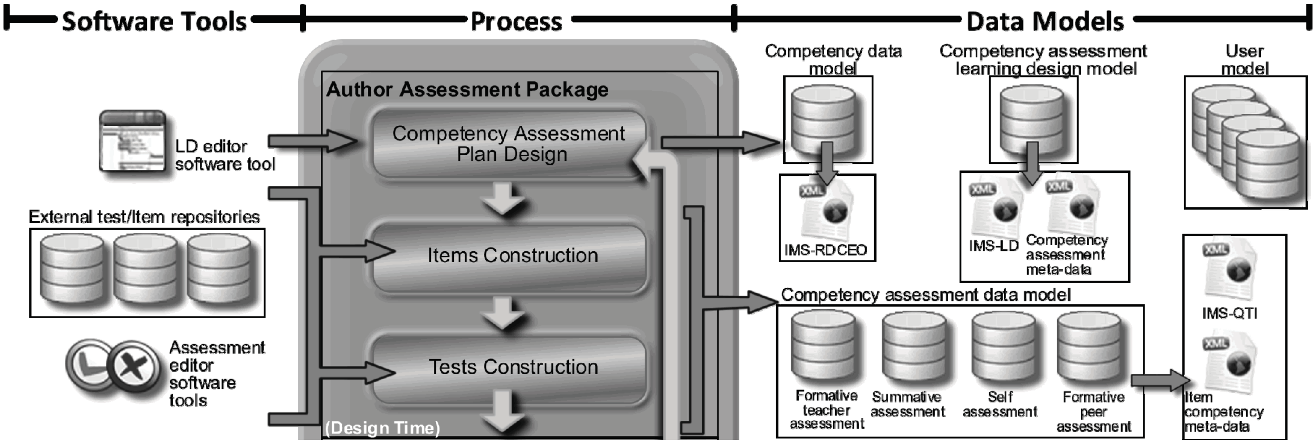

Figure 3. The Author Assessment Package of AEEA

Four data models are required for the implementation of the *Author Assessment Package*:

- *Competency data model:* this is a data model to describe the hierarchy of competencies, their characteristics and relations. Its basic specification is IMS-RDCEO [21].
- *User model:* this is a data model to describe a system user's relevant data, such as demographic information, learning style, background, etc. The basic specifications are IMS-LIP [22], IMS-AccLIP [23], and ISO-PNP [24].
- *Competency assessment learning design model*: this is a data model to describe the assessment plan and its adaptive rules. The basic specification is IMS- LD [2].
- *Competency assessment data model (CADM)*: this is a data model to describe e-assessment scenarios (formative peer assessment, formative teacher assessment, self assessment and summative assessment.) and students' results.

Three kinds of software tools are required for the *Author Assessment Package:*

- An *LD editor software tool* is used to configure the LD assessment plan where outcome variables of QTI can be coupled to LD properties.
- *Assessment editor software tools* are used to design assessment items and tests.
- *External test/item repositories* are used to store assessment items and tests.

In the *competency assessment plan design* step, an *LD editor software tool* is used to configure the *competency assessment learning design*. The *competency data model* and the *user model* are also set up inside this step.

In the *item construction* and *test construction* steps *assessment editor software tools* are used to define and to recover assessment item and test metadata from the *CADM* data model stored in the *external test/item repositories*.

IV. COMPETENCY DATA MODEL , USER MODEL AND COMPETENCIES ASSESSMENT LEARNING DESIGN

Some of the data models needed for AEEA were built by the BCDS research group before or parallel with development of the CADM.

The *competency data model* [13] [14] describes the elements of information that can be used to specify how a specific competence can be defined, developed and monitored in an LMS. The model was constructed through the analysis of different competency models and based on curricular design theories.

IMS reusable definition of competencies and educational objectives (IMS-RDCEO) is the language used to represent and exchange competency definitions. In order to implement the model proposed, a service for competency definition [25] [26] [27].was developed in dotLRN, a well-known open virtual learning environment

With a different research purpose, a complete *user model* has been developed [15] [16] [17] [18]. This model takes into account several different user characteristics and constructs a profile for each user.

The learning style profile is an enriched abstraction of Felder's categorization and is inferred through the application of his index of learning styles [28] to users. From the 44 questions in the Felder and Silverman approach considered as input, the user model is constructed as described elsewhere [29].

Two types of competency are inferred for the competency profile by analyzing the user's interactions within a number of LMS tools. Collaborative competencies are defined by analyzing the user's behavior in tools such as forums, chat rooms and e-mails. For specific competencies, three levels – novice, average and expert – are considered. These levels are related to one or more of Bloom's objectives [30].

The growing interest in mobile and ubiquitous systems has attracted researchers' attention to other dimensions of the access device profile, such as user location, physical environment, social context, and affective state. Our approach

[31] considers a number of characteristics of the user access device, in particular hardware features such as screen size and the capacity to show images, colors, and to reproduce sounds. It also considers software characteristics such as the mime types supported, character codification, availability of java and browse capacity such as the possibility of using frames, tables, java applets, and java script.

We have developed a number of projects to determine any special needs our users may have, such as learning difficulties and sensorial limitations.

The competency assessment learning design model [19] is achieved by inputting the user modeling and learning process specification.

So far, we have developed learning designs (LDs) in a deterministic way, using a competency definition and learning object metadata. The learning design generated is a cognitive but not a specific assessment design.

However, our ultimate aim is to enrich our work through the use of different retrieval algorithms and thereby increase the complexity and the specified level of LD generation and to facilitate the teacher's design task.

V. COMPETENCY ASSESSMENT DATA MODEL (CADM)

Learning management systems usually have a standard package for summative assessment. The CADM proposal therefore focuses on the development of data models for the other three types of assessment (formative peer assessment, formative teacher assessment and self assessment).

XML schemas describe, with a high level of abstraction, the structure of and restrictions on the contents of XML documents in a very precise way, beyond the syntactical rules of XML [32]. Different XML schemas are proposed in a CADM to provide the extensibility, interoperability, reusability; efficiency and abstract modeling required for the new data model. These XML schemas become an extension of the IMS-QTI specification used for summative assessment.

For each new assessment scenario, a CADM proposes two XML schemas, the first to represent assessment items and the second to represent tests. The scenarios and schemas are explained below. The schemas are shown as tables (for space reasons) emphasizing their most significant elements.

A. Schemas for formative peer assessment

Formative peer assessment (FPA) can be developed in three modalities: *individual,* when students complete their assignments alone and other students on the course peer review their work; *intra-group,* when the students work on a collaborative task in groups and each member is judged by the others; and *inter-group,* when the students on a course are divided into subgroups to carry out a task and the peer review of one group is performed by another. FPA schemas need to allow for data modalities to be set up.

The actors in this scenario are the teachers who direct protocol evaluation as e-moderators, the peer reviewers and the learners. FPA schemas need to allow for grants to be set up for these participants.

[33] suggests that to be successful, the peer evaluation process should first involve students in a discussion of the rating scale and the construction of the evaluation form. After this, the peer review can be done. As a final step, learners make changes to their work and write a report justifying the changes accepted and those rejected. This means FPA schemas should allow a rating scale to be set up and assessment items on the evaluation form to be enabled or disabled. [34] declares that peer forms must contain rich, detailed, qualitative feedback information about strengths and weaknesses, and not merely a mark or a grade. The schemas should also allow rating data and comments about strengths and weaknesses to be saved. Rating data are defined using a rubric to score the quality characteristics of the evaluation items.

Table I presents the characterization of the elements and sub-elements of the schema for FPA items and Table II presents the characterization of the elements and sub-elements of the FPA test schema.

B. Schemas for formative teacher assessment

Formative teacher assessment (FTA) must take place for all tasks on which students are assessed, so it could be carried out for individual or collaborative tasks. Assessment items represent quality characteristics linked with a level of competence acquisition. A rubric score is stored for each assessment item.

Table III shows the characterization of the elements and sub-elements of a schema of TFA items and Table IV shows the characterization of the elements and sub elements of a TFA test schema.

C. Schemas for self assessment

Students take a short test to assess their interests, skills, abilities and competencies in every task. Assessment items are linked with competencies and qualified with a general rubric score.

Table V shows the characterization of the elements and sub-elements of the item schema. Table VI presents the characterization of the elements and sub elements of the test schema.

TABLE I. ELEMENTS OF THE SCHEMA FOR FPA ITEMS

<quality_characteristic> <title> <description> <competence_knowledge> <competence_context> </quality_characteristic >	This describes a quality characteristic that can be evaluated in a student's work. Each quality characteristic is linked with a competence.

TABLE II. ELEMENTS OF FPA TEST SCHEMA

<modality> <type></type> <number reviews> <anonymous> </modality>	This describes the type of modality, number of peer reviews and a Boolean element to say whether the learner can know their peer reviewers or if the evaluations are to be anonymous.
<outcomes> <outcome> <name> <value> <competence-id> </outcome> </outcomes>	This describes the outcomes of the assessment. Each outcome is linked with a competence.
<grants> <teacher></teacher> <peer></peer> <learner></learner> </grants>	This describes each actor's or user's grants at the FPA interfaces. It determines whether a user can insert new items or areas of assessment, vote on items to include in the form, make a review or read results.
<rating scale> <min-value> <max-value> <number categories> </rating scale>	This describes the rubric score applied to assessment items. The rubric score is defined with the minimun value, the pass value, the maximun value, and the number of categories.
<items> <item> <id></id> <path></path> <weighting> <grade></grade> <item> </items>	This describes the set of items linked with an FPA test. The items are quality characteristics evaluated with a scoring rubric and a percentage weighting.
<strengths> <comment> <peer-reviewer-id> <notes> </comment> </ strengths >	This describes the reviewer's comments regarding strengths in the evaluated work.
<weaknesses> <comment> <peer-reviewer-id> <notes> </comment> </weaknesses>	This describes the reviewer's comments regarding weaknessess in the evaluated work.

TABLE III. ELEMENTS OF A SCHEMA OF FTA ITEMS

<quality_characteristic> <title> <description> <competence_knowledge> <competence_context> <rubric1-info></ rubric1-info> <rubric2-info></ rubric2-info> <rubric3-info></ rubric3-info> <rubric4-info></ rubric4-info> </quality_characteristic >	This describes a quality characteristic that can be evaluated in a student's work. Each quality characteristic is linked with a competence. The description of the rubric score scale is saved within the item.

TABLE IV. ELEMENTS OF A FTA TEST SCHEMA

<task> <type></type> <name></name> <task-id></task-id> </task>	This describes general data on the task: type of task (individual or collaborative), name and task identifier.
<outcomes> <outcome> <name> <value> <competence-id> </outcome> </outcomes>	This describes the outcomes of the assessment. Each outcome is linked with a competence.
<grants> <teacher></teacher> <learner></learner> </grants>	This describes the grants for each actor or user at the interfaces of TFA. It permits defining if a user can insert new items or areas of assessment, vote on items to include in the form, review or read results.
<items> <item> <id></id> <path></path> <weighting> <grade></grade> <item> </items>	This describes the set of items linked with a FTA test. The items are quality characteristics which are evaluated with a rubric score and a weighting.
<strengths> <comment> <teacher-id> <notes> </comment> </ strengths >	This describes the teacher's comments about strengths in the evaluated work.
<weaknesses> <comment> <teacher-id> <notes> </comment> </weaknesses>	This describes teacher's comments about weaknessess in the evaluated work.

TABLE V. ELEMENTS OF SELF ASSESSMET ITEM SCHEMA

<quality_characteristic> <title> <description> <competence_knowledge> <competence_context> </quality_characteristic >	This describes a quality characteristic that can be evaluated in a student's work. Each quality characteristic is linked with a competency. The description of the rubric score scale is saved within the item.

TABLE VI. ELEMENTS OF SELF ASSESSMET TEST SCHEMA

<task> <type></type> <name></name> <task-id></task-id> </task>	This describes general data on the task: type of task (individual or collaborative), name and task identifier.
<outcomes> <outcome> <name> <value> <competence-id> </outcome> </outcomes>	This describes the outcomes of the assessment. Each outcome is linked with a competency.
<grants> <teacher></teacher> <learner></learner> </grants>	This describes the grants for each actor or user at the interfaces. It permits defining if a user can insert new items or areas of assessment, vote on items to include in the form, review or read results.
<rating scale> <min-value> <max-value> <number categories> <rubric1-info></ rubric1-info> <rubric2-info></ rubric2-info> … <rubricN-info></ rubricN-info> </rating scale>	This describes the rubric score applied to assessment items. The rubric score is defined with a minimun value, a maximun value, the number of categories and their descriptions.
<items> <item> <id></id> <path></path> <weighting> <grade></grade> <item> </items>	This describes the set of items linked with the test. The items are quality characteristics evaluated with a rubric score and a weighting.
<strengths> <comment> </comment> </ strengths >	This describes students' own comments about strengths in the evaluated work.
<weaknesses> <comment> </comment> </weaknesses>	Ths describes students' own comments about weaknessess in the evaluated work.
<findings> <comment> </comment> </findings>	This describes students' own comments about findings in the evaluated work.

VI. CONCLUSIONS AND FUTURE WORK

Assessments play a significant role in the competence acquisition process and there is a clear need to run interoperable and adaptive competence assessment tests in LMSs. The traditional summative assessment of LMSs must be accompanied by other types of assessment. Metadata about assessed competencies must be defined and monitored throughout the e-learning process, and therefore the competency data model, learning design and assessment must work together.

In this paper a competency assessment data model is proposed as part of AEEA implementation. Three new types of model are proposed (schemas for formative peer assessment, formative teacher assessment and self assessment) as an extension of the IMS-QTI specification. Competency data are introduced in assessment items and test metadata. Other research is integrated to implement the author assessment package of AEEA.

Our work is now focused on the first package of AEEA implementation, in particular on developing assessment editor software tools, the integration of a competency data model with competency learning design and a CADM, and also on preparing assessment items in different repositories.

For the future, we plan to implement assessment software tools such as dotLRN and Moodle services and provide proof of the design-time architecture.

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On Education Quality Control Issues for Sino-France Hybrid Engineer Diploma

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Abstract—**Quality control in higher education is a complex social key project fostered by the Chinese government. As a sino-foreign cooperation school in engineering, we are focusing more intensively on quality control in higher engineering education. Sino-European School of Technology of Shanghai University (UTSEUS) was established by Shanghai University in cooperation with University of Technology Network (France) in 2006. Dual-campus education program has been introduced to UTSEUS ever since: two years of campus life in China, and the next two years in France. Challenges on the program designs, the teaching modes, the teaching strategies, teaching quality control and teaching collaboration have been updated accordingly concerning the different educational systems we have in China and that in France. With monitoring the dual-campus engineering education, several approaches have been introduced to the quality control of higher engineering education in UTSEUS.**

Keywords- quality control, Sino-European cooperation, dual-campus teaching, teaching assessment system.

I. INTRODUCTION

With our knowledge broadening continuously in the ever-changing 21st century, the problems that we are dealing with have also become ever more complex.

Driven by the economic globalization, the world's need for engineers with an international background is accelerating in the multinational enterprises (MNE). To answer the call of the times, we feel the urge to nurture our engineering majors with a global and innovative mind, which is also the trend of internationalization of higher engineering education in China. In 2006, UTSEUS was officially established by Shanghai University (SHU) with University of Technology Network (UT) of France—University of Technology at Compiegne, at Troyes and at Belfort (UTC, UTT and UTBM). Accordingly, preeminent professors and courses were introduced to UTSEUS from France in order to answer the call of globalization.

It is widely known that engineering education is shifting itself from mere technology education to research education. Teaching method patterns in Shanghai University are in the transition from instructional-based to research-based. Through the study of the model and experience employed by the UT groups, the practice on teaching modes, teaching strategies, teaching quality control and teaching collaboration in dual-campus engineering education system utilized by UTSEUS has been implemented. This paper is to discuss how to manage the quality control in higher engineering education and what UTSEUS has accomplished so far in this field.

II. QUALITY CONTROL IN HIGH INTERNATIONAL ENGINEERING EDUCATION

More and more universities have realized that mastering the techniques is not enough for the engineers of 21st century. It can be a niche for them to comprehend corporate management and the social culture as well.

Our engineering majors should be able to design and practice with a global and innovative mind. International engineering education with a dual-campus system is popular worldwide. Therefore, it is important to find effective approaches to control the educational quality under such system, which is the preoccupation and priority for our international engineering school to design a appropriate program.

Considering the massive and growing market yearning for engineers with an international background, the universities need to adjust their teaching methods. Nevertheless, what key characteristics should such an engineer possess?

In 2001, the United States National Academy of Engineering (NAE) and the United States Natural Science Foundation (NSF) co-sponsored the "2020 Engineer" program. By the end of 2004, the program issued its 1st official report on "2020 Engineer: The vision of engineering development in the new century"; in 2005 summer, they released the 2nd formal report on "Training of Engineers in 2020: engineering education to adapt to the new century" These reports analyze the engineering practice, the technical, social, professional, international backgrounds and etc, which describe in detail the expectations and characteristics of the future engineers.

Engineers in year 2020 should have analyzing capability, practical experiences, creativity, communication skills, business and management expertise, leadership, ethical consciousness, and life-long learning desire. The report describes a qualified engineer for our teachers, employers and students.[1]

With the continuous development of higher engineering education, the traditional mentoring educational model has been replaced and the elite training model has also been diluted. Nowadays, the higher engineering education is available to larger population of students. Meanwhile, the need of the enterprises for elite professionals is on the rise. Considering all the previous aspects, higher engineering education and its reform must be monitored in light of quality control with its evolving management models and tools.

In the traditional method, quality control is to "discover talents and enable them to maintain excellence".[2] Faced with such massive demand of professional engineers, we feel it our responsibility to cultivate the qualified engineers that will meet the need of the industry and ensure every step in the teaching process with the quality control system. Numerous research projects on Quality Management in Education (QMIE) have been carried out by those prestigious universities renowned in engineering, such as the "CSE model" by UCLA (University of California, Los Angeles). But it is difficult for a school with dual-campus system to control the quality in education via the traditional approaches. It is beneficial for us to learn from the industry in order to update our approaches of quality control. Total Quality Management (TQM) is the most intensive means in quality control. TQM system is based on the information integration technology, takes combination between quality control and quality management as main principle, and fulfills enterprise's long-term operating strategies finally.[3] And thus, it can be an appropriate quality control approach in international engineering education.

According to the essence of every TQM approach, we can find the corresponding approaches in quality control at different stages of the quantitative management in education, which includes control of pre-teaching design, teaching process control, and teaching quality assessment.

III. Control of each teaching phase

A. Control of pre-teaching design

During the stage of pre-teaching design, the priority is to design the appropriate teaching program and curriculum planning.

Teaching program is the blueprint in assisting the achievement of the basic goals and specifications of education. The gist is the implementation of program with specifications of monitoring and evaluation in quality of education. Therefore, it is ideal to have a team of experts to monitor the quality of design and practice of the teaching program.

The evaluation of the programs in the University of Massachusetts presents a type of quality control in terms of teaching design. They put forward several points concerning quality control of the programs as follows: (1) How does the professional guide the content of programs; (2) Does teaching scheme meet with contemporary needs; (3) Whether the structure of the programs is logical, sequential, and coherent. How about the field operations, test operations, seminars or other large-scale operations and so forth help students acquire and integrated what they learned? (4) Does programs really enable students properly to prepare further study or employment?[4]

At UTSEUS, four majors are tailored with their own teaching programs respectively. Given the four-year program, it is urgent for us to adjust the program to meet the growing need from the market and retain the quality as well. Having carried out a survey in a large scale with the assistance of the cooperative school in Shanghai University and the prior four-year experience, we feel even more confident in reforming the program of mechanics to start with. Since the undergraduates with engineering backgrounds are popular amongst the enterprises, the teaching program has been reformed or changed according to these needs. With the two-year reform in teaching program of mechanics, our students not only have more access to practical training, but also refresh their understanding with the major.

Curriculum planning is the detailed part of the teaching program, which should be designed by specialists as well.

In the process of designing the teaching program and the curriculum planning, the first step of TQM is fulfilled. The criterion of education quality control is confirmed. Accordingly, the top-down structure for TQM can be devised with the criterion.

B. Control of teaching process

With the dual-campus system, the students in UTSEUS first spend three to four years studying in China, and then, they can choose to study another two years and a half in France in order to attain the engineering diploma or two more years to gain a master degree there instead. Due to the different educational systems between the two countries, divergent teaching processes are therefore lied between the Chinese and French professors. The cooperation courses in UTSEUS will be helpful to students to adapt to the model of engineering education in France. On that account, in UTSEUS, there are approximately 17 courses taught by French and Chinese teachers in the whole learning package .

Considering the two nations' different teaching models, it is important to find more effective approaches to practice quality control in education during the teaching process. By analyzing the four-year practice in UTSEUS, it is clear that the people are the key factors in quality control in such teaching model. As it is emphasized in TQM that everyone in an organization should support and participate in the quality control procedure which is carried out in the organization. The first step of quality control in teaching process is to have all the teachers and students realize the importance of implementing TQM in the teaching process. If each teacher participates in the quality control of the teaching process, it will be a good opportunity to form a standard procedure for cooperation course in dual-campus.

French professors are not able to carry out their long-term teaching plans in UTSEUS because of the short-semester practice in the Shanghai University. As a result, a team of more experienced French professors are formed. The courses taught by them are thus carried out. The question is, how to assure the quality of teaching process with such a team? First of all, we have an experienced French professor to be the head of the teaching team. He will find and organize his teaching team. The object and the quality of the course depend on his design. In order to keep the teaching process effective, the teaching team is composed of several French professors and one to two Chinese professors. It is also the team head's responsibility to keep all the team members communicating effectively and efficiently. According to the different teaching methods and teaching concepts between the Chinese professors and the French professors, the division of teaching part of Chinese and French professors will be well planned approximately one year prior to the commencement of the course. Although each professor teaches one part of the course during the teaching process, the joint content is designed and monitored by the team head. This structure of teaching team and course design is practicable in the teaching process of the dual-campus, which can also sustain the teaching quality on an average level.

Then how to improve the quality of such course? We need the help from our students and advanced information techniques. Considering the characteristics of teaching in dual-campus, we designed a platform called "open-course-ware" to assist the teaching team to improve teaching quality. On such platform, students can present his problem and put forward his suggestion to the teaching team. It will help the head teacher of the team adjust the course to benefit the students in time. Then there will be good effect at the end of the teaching process. Of course, the effect of the course will be measured by a evaluation survey. The traditional evaluation on teachers is replaced with the evaluation on courses. The results of course evaluation are the reference to the academy and the teachers.

There are still a lot of courses only taught by our Chinese teachers in UTSEUS. These courses are within the framework of teaching managements in Shanghai University. Experienced professors in Shanghai University will evaluate the teaching process of specified course occasionally and submit their opinion by reports. The same evaluation standards are applied to the courses taught by Chinese teachers.

Therefore the teaching process quality control in dual-campus should focus on the approaches of motivating both teachers and students. The teachers should design an efficient method to organize the course. And it is important for them to teach with an open manner and positive attitude.

C. *Evaluation of teaching quality*

We can evaluate the quality of teaching by two methods: evaluation of students and evaluation of curricula.

a) Evaluation of Students

The evaluation of students can also reflect the quality of our education. Our purpose is to develop high quality engineering, so our evaluation of students must be suitable to this purpose. By traditional method, we evaluate students by their absolute score in the examination. It may reflect how many contents students have mastered and how well they master the knowledge. But its reflect-function depends on that the exam is normative, rational and has reasonable difficulty. Moreover, the absolute score can not reflect the student's location in the course. Students may focuses on refining results excessively. This is not the characteristics of a high quality engineer.

In UTSEUS, we have introduced European Credit Transfer System (ECTS), which is a relative score evaluation system, to reform the traditional evaluation. Through using ECTS, we can efficiently overcome the disadvantages brought by the absolute score system. It will help us to encourage students to compete healthily, promote them to improve their studies continuously and let them develop their self-learning ability.

Based on using both absolute score and ECTS, we adopt an all-round evaluation model to evaluate the students' academic situation. In reference to the absolute score and ECTS of students, we establish a mode of communication called "assessment conference". In this conference, we analyze students' learning comprehensively, assess their academic achievement and pay more attention to their development in the future. And the most important focus we consider is the trends of students' learning.

With four-year practicing, 63% of our first students have finished their 3-year studies in UTSEUS and gone to France for their studies for Engineering Diploma.

b) Evaluation of Curricula

Evaluation of teaching at universities is traditionally realized in terms of student ratings. Curriculum evaluation is rarely done in a systematic manner. More often, the emphasis is placed on a particular aspect, which is only of little help in terms of modifying education. Christine Spiel introduces five phase of evaluation to be considered and contrasting results to others. The first and the concentrated phase is the baseline evaluation. Especially, while a course is under reformation, the evaluations of it should primarily focus on new curricula by contrasting it to traditional ones. [5]

UTSEUS has learned the experience and method from UT groups, and established our own method evaluation of curricula. With traditional evaluation, students will give a course or a teacher a grade to evaluate its teaching quality. Considering our own characteristics, we have a teaching group working on the course, it's not reasonable to value one teachers on one course. So we concentrated on the course itself. We have the students to fill a form, which is about the course, including teaching method, teaching content, and the detailed feeling about the course by students, etc. With the result of this form, we can learn the general information about the quality of this course. By collecting the information and suggestion given by students, we can analyze the reformation of the course and suggest the teaching group to adjust the teaching method. By means of evaluation, several courses have improved its teaching effect obviously, and our cooperating colleagues will be much more glad to teach and do reform in UTSEUS.

IV. ADVANCED INFORMATION TECHNIQUES

A. *System Architecture*

An online education assessment system is under development. The system was initially designed as PHP + MySQL architecture, but due to the database of UTSEUS is not a completely independent system, which relies on the raw score provided by Registry office and basic personal information provided by student's affair office of Shanghai University. In order to share the public information platforms of the campus and reduce the maintenance cost of infrastructure of data and database server, the database was migrated to the Microsoft SQL Server solution.

There are views and stored procedures running on the SQL server for complex computing tasks, reducing the data exchange between database and application server to improve network performance and reducing the complexity of application development, applications and end users to focus on aesthetic interaction and a clear presentation of data.

A flash library named as “The Open Flash Chart” is being delivered by LGPL. It can be a graphical front-end display of statistical data. The database statistical data is read by PHP and the OFC class library transfer output data into a JSON (JavaScript Object Notation) format, sent to the open-flash-chart.swf object, it can draw a lot of kinds of charts on-line output.

A Moodle site is set to provide e-learning services in UTSEUS. The Moodle system is an open source software based on PHP. The low layer libraries of Moodle are well developed, it includes classes and functions covered database abstract and User managements. The base codes can be reused in new software development. The applications integrated in moodle seamlessly with the benefits of mature user authorities and privileges mechanisms. By modify some core codes of Moodle we made it fit the education activities of UTSEUS well.

B. Applications Oriented to Quality Control

Figure1 is a transcript of a student in UTSEUS, a self-developed program convert a Shanghai University Score System to the ECTS and GPA system. On this page, a GPA performance chart is given to show the trend of a specified student, progress or retrogress.

Figure.1 Transcripts

Figure2 is Zoom of GPA performance chart. The green dot-line is semester GPA, the red dot-line is final GPA and the blue dot-line is French course GPA.

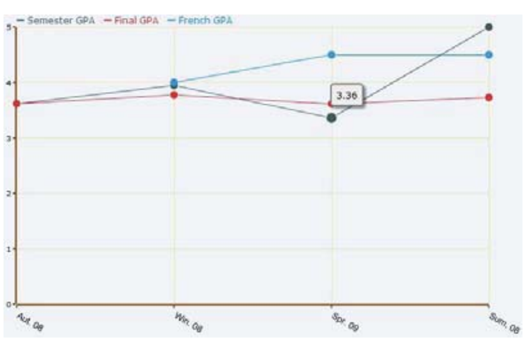

Figure.2 Zoom of GPA performance charts

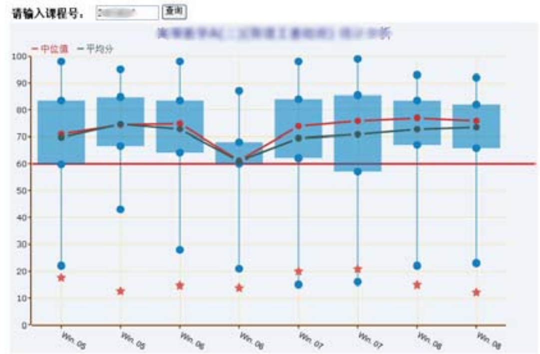

Figure.3 Box Plot for course quality analysis

Box plot, also known as box-line diagrams, is a box and two line segments graphics indicated by five eigenvectors which include maximum, minimum, median and two quartiles. "Single course quality analysis map", highest point of each box is a specific the highest score of the exam when a semester is over, the next point is the student who in the top quarter, the third point is the score in the top three quarters, the lowest point is the lowest score(except 0)of the test (lots of reasons not directly associated with learning level cause 0 point such as absence of test, cheating, so 0 point is not included in statistics), the red dot is the median value that means the score of half ranked score of the exam. The box is the distribution of the middle half ranked score. Box plot graph characterizes the distribution of results, in general, a large dispersion implying a no good quality of education. Formula for the overall standard deviation formula is as follows

$$\sigma=\sqrt{\frac{\sum_{i=1}^{n}(x_i-\bar{x})^2}{n}}$$

The standard deviation can be more precise to describe a number of discrete levels of data, and its unit is the same as the input data; The asterisks in lower part of the chart is the standard deviation of the exam results. Visual comparison in a box plot diagram, with a large polymerization there’s a small standard deviation, and on the contrary with a small polymerization there’s a large standard deviation. The second box-plot reflects the desired result of a exam (Calculus of winter semester in 2005) with high average and low dispersion; the sixth box-plot (exam result of Calculus in winter semester, 2005) indicates poor quality of teaching with even the box of middle ranks crossing the pass line and the difference of the highest score to the lowest is large and the overall dispersion is large. When the mouse moves onto each box, the teacher’s name and related information will be shown in a float label.

Figure 4 is a final GPA of all grades in subparagraph (>= 3 and< 2.5) percentage of charts, dashed line for the French course GPA. Figure.5 is a specific semester GPA for all grades compared, each column is a grade. The information system gives these charts automatically. Statistics and data mining is an emerging field, new methods and new techniques emerging, In future research, more statistics and analysis of score will be integrated into the system.

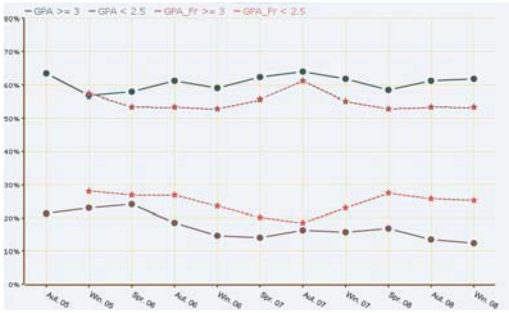

Figure.4 A specific grade divided by the cumulative semester GPA Analysis

Figure.5 A specific sub-semester GPA for all grades compared

To analyze the relationship of studying in China and in France, Pearson correlation coefficient is introduced. For the score data are continuous and approximately normally distributed, fit the condition of Pearson coefficient. The result is the Pearson coefficient is around 0.4~0.5. The significance is 0.01 that means the result is acceptable.

V. CONCLUSION

The quality of engineering education is the most important support for an engineering school. As a sino-european engineering school, we have the duty to do well in quality control of our engineering education. Since there are so many aspects in the quality control of education, the first thing we try to do is to design a schedule and blueprint to guide our efforts in this job. As is said above, we have some successful experience in evaluation of students and curricula. It's time to synthesize the evaluation method to integrate into a general system. It's a long-term work to design a perfect culture program. But we have to determine our standard about the evaluation of the program, and then we can do a good job in designing and reforming the culture program. On above topic, we do the quality control on the whole procedure of teaching and have got successful experience in evaluation stage. In the future, the teaching process quality control may be the second emphasis to improve. While we have the clear and determined goals (programs) of education, we should do the quality control in teaching process (including teaching method, teaching standard, etc.), and when the course finished we can use the evaluation of students and curricula as a feedback system to our quality control system.

Statistics and data mining is an emerging field, with new methods and new techniques emerging. In our future research, more statistics and analysis of score will be integrated into the system.

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Assessment of learning activities in discussion forums online

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***Abstract*. - This is a report intended to describe a research about assessment of learning activities done in a virtual forum. Student's messages in the forum as a whole were considered as analysis unit. It was employed a content analysis technique to identify characteristics involved in the messages. Categories and indicators for analysis were defined from the Community of Inquire Model, adapted specifically for mathematics courses. Examples selected as a guide for learning activities assessment are shown, in terms of number and type of participation, as well as result from linear correlation analysis between numbers of participations to each category.**

***Keywords*.- Inquiry community, social, didactic and cognitive categories.**

I. Introduction

Interaction in virtual forums has been studied by several researchers. They have analysed different aspects of interaction [1, 2, 3, 8, 10, 12, 14]. To consider knowledge construction caused by students interacting in forums is a methodology for making inferences by sistematically and objectively identifying defined characteristics in the messages. Van Diijk analysis [12] includes considering the quality of language employed, beliefs that arise in social interaction. Everyone's contribution bears an own meaning and must be considered individually.

A remarkable method is the codification method proponed by Henri [8]. Accordingly, there must be distinction between participation and interaction categories, because number of participations is not a valid indicator to verify quality of interaction. Anderson, Garrison and Rourke [1, 5, 11] have developed the Community of Inquire Model to analyze interactions and learning processes in virtual forums, which is consistent with the constructivist proposal for learning.

II. Community Of Inquire Model

For this model it is supposed that the learning process is integrated by three central components: Social, didactic and cognitive dimensions.

Social dimension is defined as student's skill to communicate social and emotionally into the learning community by means of messages; with those messages students build personal relationships, settles affective communication and develops social ties, and so there is an environment necessary for the group to feel safe for open communication and behold around common goals.

Didactic dimension deals with designing, facilitating and guiding social and cognitive processes, intended to achieve meaningful learning [1].

This dimension can be seen in the forum as messages between teacher and students to accomplish the course goals, which means to decide about resources, programs, study guides, methodology, contents, discourse, activities and deadlines. As course designer, the teacher inherits a key role, but it must be taking into account that in a course with constructivist approach responsibility is not exclusive for her/him.

According to Anderson [1], contributions to this category may surge from anyone collaborating to implement the didactic role.

Cognitive dimension. Garrison [7] defines cognitive dimension as the level to which students are able to construct and confirm meanings through reflection and dialogue within an inquiry community.

This dimension is based on critical thinking which could be understood as a process, as well as a result. As a product it refers to acquiring deep and meaningful understanding, which is perceptible in the different assignments elaborated by students. As a process it is considered that critical thinking acquisition may be enhanced by understanding how it is accomplished.

It is important that in this research the term "category" instead of " dimension" or "presence", as used by Marcelo [10] and Anderson [1], correspondingly.

III. Methodology

The need for original indicators was perceptible when first trying to categorize the messages put into the forum, according to the definitions made by those authors and found several situations not included in. Therefore it was generated a first set of original indicators, to try a new scale to categorize messages submitted to the forum.

Considering this new scale, indicators were redefined, in a way that the new set of indicators was suitable for two consecutive categorizations that produced same results. For each indicator, significant samples of text were collected.

The content of each message submitted to the forum was analyzed according to the previously defined indicators. When there were found one or more indicators, then it were considered that the message contained a collaboration of the type of the indicator and so it was counted. A message might include only one category indicators or two or three categories simultaneously.

IV. RESULTS

An important part of the study was adapting the Community of Inquire Model to the specific characteristics of the selected course. In Tables 1, 2 and 3 defined indicators for each category are shown, as well as significant samples of text, taken as guiding examples in the categorization (Note: Phrases in tables 1, 2, 3 are taken literally from messages submitted by students to the virtual forum. S.A., V.C., C.T. and J.C. are the initials of students' names).

TABLE I. INDICATORS TO CATEGORIZE, AND EXAMPLES OF SOCIAL CATEGORY

Social Indicators	Examples
Expressions about emotions, feelings and moods.	"Welcome fellows, I'm happy to work with you" "… I feel stressed because S.A. does assignments pertaining to future and gets parts that do not belong to him"
Jokes, irony, sarcasm or mockery expressions.	"You can't stand against women. I agree with you!!! (Just kidding!!!!)"
Comments about aspects not related to the course, as everyday life, personal communications.	"My computer is in trouble and I'm working in a public facility" "Do you know when are we having the i.d.'s to obtain books from the UDG library?"
Support, appreciation, recognition, grateful, displeasure and apology expressions.	"If is there any question from the assignment that you consider that I may help you, I'll do it with pleasure". "I'm sorry, I faced problems with my computer"
Comments not related to course contents.	"If you don't notice until now, we are the only team that has send assignments to the folder in the platform." "You may purchase online the Pita Ruiz book at Santa Fe book store"
References to other classmates' messages or assignments.	"... that is why V.C. says: We first rewrite..." "The J.C.'s answer may help to solve the problem." "...on exercise 1 I agree with J.C...."
Using classmates' first name to address them.	"C.T., I already have checked the exercises you send."
References to the Group, using expressions as we, ours, our Group, classmates.	"...we have to put together our parts to conform just one document for the assignment..." "My fellows, my proposal is..."
Etiquette of Communications, greetings, welcomes, farewells, etc.	"Hi everyone" "Please install..." "Greetings"

TABLE II. CATEGORIZATION INDICATORS AND EXAMPES OF DIDACTIC CATEGORY

Didactic Indicators	Examples
References to program, work methodology, assessment criteria and deadlines to submit assignments.	"To sustain your messages and answers you must define and interpret the concepts involved..." "Write formulas with the equation editor" "The limit to deliver assignments 1 and 2 is the 19.02.07."
References to platform, or available resources.	"Please install the Skype program..." "...how do you put the vertical line in the augmented matrix when in the program...?" "Please consult the study guide …"
Agreement or disagreement expressions about assignment of activities.	"Hi, I agree." "I don´t agree with that …I told you I was to do exercise 1"
Expressions to direct dialogs and activities to achieve course objectives and learning construction.	"Hi Partners: What is the strongest argument to solve an equation system?" "It's necessary further work for assignments 1 and 2 because there are several failures..." "In problems … matrices are second degree and in …,third degree, therefore it would be convenient distribute them so that you every one receive a problem from each first and second parts"
References to contents, tutoring and questioning.	"In general, the number of transpositions depends of …" "What's the use of permutations parity and product of substitutions?" "Te concepts permutation and substitution are basic for learning the concept of determinant."
Requests and judgment expressions about own or other's work.	"Excellent answers." "Your explanation is quite complicated". "...in order to clarify your conclusion it would be good to indicate that parameters ann and b are different of 0."
References to additional information sources.	"The teacher put in the home page some tips … so we can put in just one format the assignment" "see examples in the adjunct file" "... it was consulted in the editorial Alianza book, and the researcher familiar matrices..."
Comments about development and completion of assignments.	"I'm sending you what I have done about assignment 2..." "... yesterday I didn't send the assignment, but for sure I'll send it today." "...I suggest putting in the platform the drafts of your shares for the assignments..."

TABLE III. CATEGORIZATION INDICATORS AND EXAMPLES OF COGNITIVE CATEGORY Y

Cognitive Indicators	Examples
References to the problem, indicating what is known and asking about unknowns.	"I solved 5.1 and found the X substitution, from knowing that the substitution product is associative for any finite number of substitutions. I'd like to know if you found another method..." "I have calculated the range of matrix 2.1 from the maximum order of its minors different from 0. Is it valid? Or it has to be done by calculating the number of no-null rows of the scaled matrix from the given matrix"
Expressions about difficulties to problem understanding, and confusion.	"Regarding problems from exercise 2, I don't know how to verify the solutions..." "I can't finish exercise 1.3..." "I don't understand exercise 3.3."
Comments to share and explain problem solving strategies.	"...watch how I did exercise 2.3. I'll try to explain to you with words. You begin with the first number of the row..." "A general comment is that your solutions are correct and well founded by deduction, but there are some alternative solutions..."
Agreement or disagreement expressions about assignments.	"...I considered that is a correct answer, but the deduction is not" "Juan Carlos told me that ... Is it true? I think ..." "Are you sure that is the correct answer? How can you probe it?"
References to information gathering and/or teacher and students suggestions	"...thanks for the observation, with that I finish exercise 1.3," "Considering the exercise 1.1 that our partner C.T. has solved, I noticed that I have missed to locate..." "It was useful for me to see the way you deduce the requested equation, in fact it's easier than the one I used."

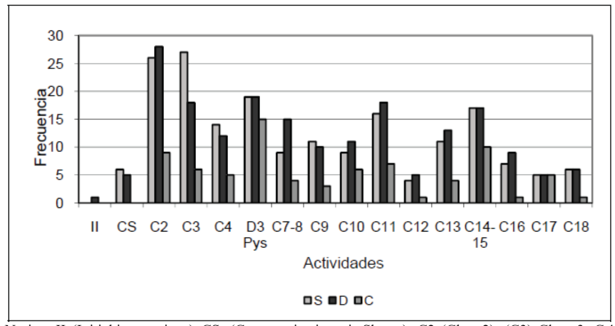
At the virtual forum participated eight students and a teacher, all of whom submitted 321 messages; when using Content Analysis with defined categories and indicators, there appeared 617 collaborations distributed as shown in Table 4. There is noted that the number of collaborations is close to two times the number of messages; this relationship shows how most messages include more than one category (Note: Teacher collaborations are included in distribution by categories).

TABLE IV. DISTRIBUTION OF CONTRIBUTIONS TO VIRTUAL FORUM IN CATEGORIES

Description	Frequency	%
Contributions to forum	617	100.00
Teacher contributions	174	28.20
Students contributions	443	71.80
Contributions to social category	252	40.84
Contributions to didactic category	269	43.60
Contributions to didactic category	96	15.56

Data of Table 4 show that the number of collaborations of each category is different. The number of collaborations of social category (S) and didactic (D) are similar (252 and 269 respectively), while the cognitive category (C) just had 96 contributions. This distribution seems reasonable for it corresponds to collaborations submitted to virtual forums where students and tutors direct their learning process through debating course contents [1].

It was observed that the amount of participations corresponding to each category was different for each learning activity, this suggest a variation for each category along the development of the course (Fig. 1).



Notice: II (Initial instructions), CS, (Communication via Skype), C2 (Class 2), (C3) Class 3, C4 (Class 4), D3 Pys (Discussion 3. Permutations and substitutions), C7-8 (Class 7-8), C9 (Class 9), C10 (Class 10), C11 (Class 11), C12 (Class 12), C13 (Class 13), C14-15 (Class 14-15), C16 (Class 16), C17 (Class 17), C18 (Class 18).

Figure 1. Histogram to show the number of each type of participations in the activities indicated along the course.

Figure 1 shows also a trend towards a reduction in the number of participations as the course progress. Such trend is noticeable for each three categories. The reasons for this decrease are not the same, but it could be said that for this particular course, students communicated directly among themselves using skype as syncronous media, skiping the possibility for registering those communications.

In Figure 2 the corresponding rates of participations in the activities are presented graphically. It can be seen as the rate between the types of collaborations remained relatively constant in spite that, as previously stated, the number of participations decreased along the course.

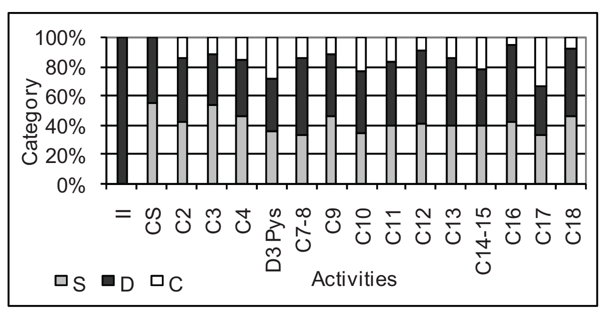


Figure 2. Rate between number of collaborations from each category in learning activities.

To de scribe the rea ltionship be tween the socia l a nd didactic collaborations a frecuency polygon is pre sented. In Figure 3 it ca n be appreciated t hat soc ial category prevails slightly over the didactic one in the first t hird of the course, and then it reverts for the rest of the course.

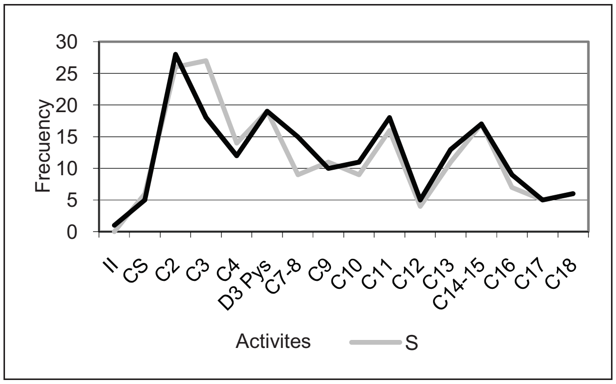


Figure 3. Rate between the number of collaborations from each category within the learning activities.

That slightly larger number of collaborations from social category with respect to the didactic one, may be devoted to the initial need for creating a community sense in order that students feel confident to participate. Once this environment is stablished there may be a slight decrease in the number of affective social collaborations and open comments, because social reinforcement is not needed as previously [13].

Regarding cognitive co llaborations i t c an be see n in figure 4 that the y appear until th ird activity (Cl ass 2), this occurs as th e fi rst and second a ctivities (In itial In structions and communication via Skype) were directed to describe the methodology to use and communication media.

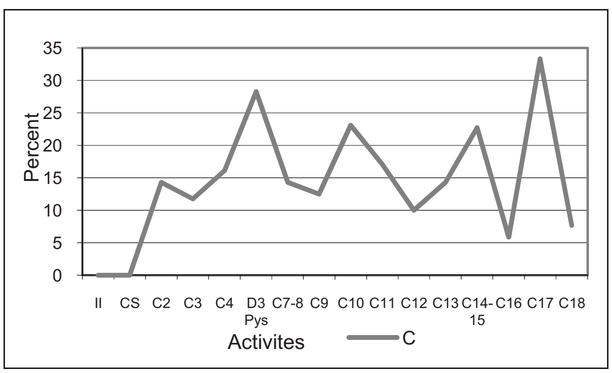


Figure 4. Percent of cognitive collaborations in course activities.

It ca n be seen in F igure 4 th at t he perc ent of cognitive collaborations alo ng the course cha nge fro m 3 to 33 %. It increased fro m 23 t o 33 % when it was in dicated in t he forum to c heck and co mment home work pr oducts, accordingly to provided indicators.

During sessions (Discuss ion 3, P ermutations an d substitutions, Class 1 0, Classes 14, 15 and 17) st udents had to assess their own product and those from their classmates, in order to indicate amendments.

This beha viour is congr uent w ith t hat d escribed by Garrison [7] rega rding how que stions or tasks proposed in the virtual forum influence t he type and level of cognitive activity of students.

The var iation in the rate of cognitive c ollaborations i n the forum als o agr ees w ith Ga rrison [7]. He st ated t hat cognitive activity is done in "research cycles" when students progress purp osedly from un derstanding the pro blem towards s uperior c ognitive le vels such as exploring, integrateing and application.

From t hese descr iptions, data m ake believe abo ut a plausible c orrelation between the n umber of ea ch ty pe of collaboration. For fur ther a nalysis i t w as con sidered t he frecuency st udents col aborate t o e ach c ategory. Usi ng this data i t was i nvestigated line al correlation between t he number of c ollaborations of e ach couple of ca tegories social-didactic, social-cognitive and didactic-cognitive.

Pearson coefficients for each case are shown i n Table 5. It can be seen that for all the cases there was a high positive linear correlation.

TABLE V. LINEAR CORRELATION BETWEEN THE NUMBER OF COLLABORATIONS TO THE CATEGORIES

Categories	Pearson's correlation coefficient r_{XY}	t_{table}	t_{cal}
Social-didactic 0.	9926	1.9432	20.0787
Social-cognitive 0.	8916	1.9432	4.8236
Didactic-cognitive 0.	9239	1.9432	5.9162

When usi ng th e t p robe f or ea ch correlation coefficient with $\alpha = 0.05$ and 6 fr eedom de grees, nul l h ypothesis H_0 were rejec ted, as they re flect that there is no e vidence of linear correlation for the number of collaborations from both categories considered ($H_0 : r = 0$ and $H_i : r > 0$).

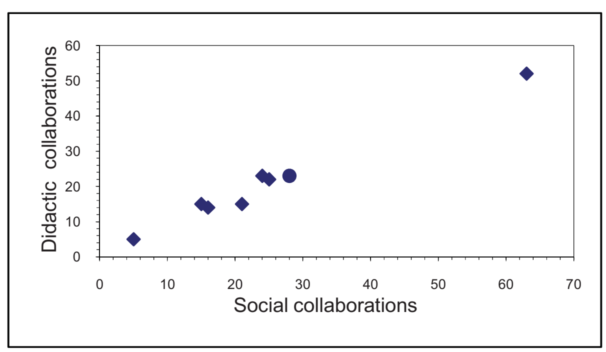


Figure 5. Linear correlation between social and didactic collaborations (r=0.9926).

Therefore it was stated that there is evidence of a linear relationship, meaningful statistically between the number of social and didactic collaborations (Fig. 5), social and cognitive (Fig. 6), as well as for didactic and cognitive collaborations (Fig. 7).

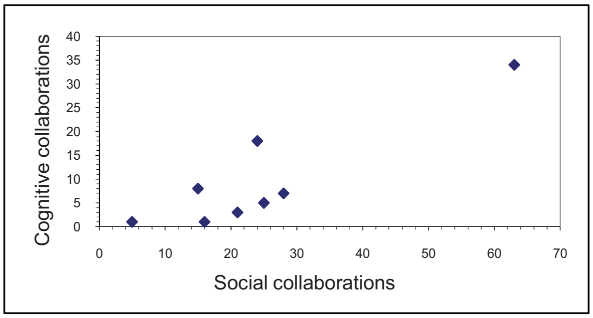


Figure 6. Linear correlation between social and cognitive collaborations (r=0.8916).

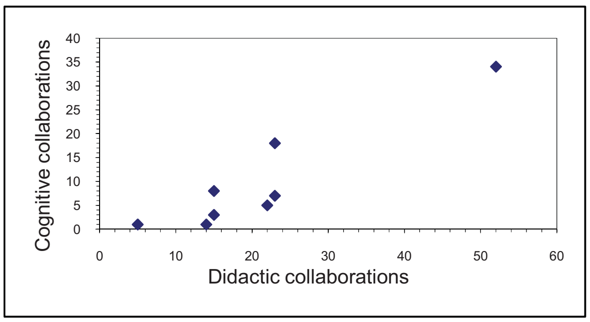


Figure 7. Linear correlation between didactic and cognitive collaborations (r=0.9239).

These results agree with those of Garrison [7] about how those three categories are highly related; how social and cognitive categories influence the didactic one, and how cognitive category in a virtual forum can be created and supported [4]. Garrison Anderson and Archer [4] suggest categories intertwine; they are not isolated from one another.

According to Garrison [7] a high positive correlation between the number of social and didactic collaborations may be explained for most social interchange are related to learning, common purposes and research.

Linear correlation between social and cognitive collaborations was previously recorded by Garrison, Anderson and Archer [6], they explain how ideas interchange, proposing solutions and comfort feeling to participate in discussions, expunge simultaneously social and cognitive sides.

High correlation between didactic and cognitive collaboration frequencies confirms as previously stated about how tutor questioning and tasks requested play an important role to develop the cognitive category.

Finally it can be said that result from using the statistic probe *t Student* indicate that social, didactic and cognitive categories are strongly related as described by Garrison [7].

V. Conclusion

From results it can be said that using this model was useful for studying the development of learning activities in the virtual forums. It could be convenient for designing future courses in similar contexts.

Data collected employing indicators defined for this research can be useful as an assessment instrument for student performance in the forum, besides, they are useful to assess the effect of learning activities designed to impulse knowledge building (cognitive category).

Frequency measurement of collaborations to each category was used to find and understand collaboration patterns, however this is not a quantitative research purposed for statistical inferences. But it was a first approach to understand and explain the complex development of online learning activities. From this perspective goals were accomplished.

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SOA-based Architecture for a Generic and Flexible E-assessment System

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Abstract— **In the last decade, universities and higher education institutes have become more and more interested in using computers to deliver their formative and summative assessments. Therefore, several computer-assisted-assessment systems have been developed. The variance in the application domains of e-assessment has a main influence on having different assessment systems in the same university. Since universities have different colleges and specializations based on their types and in order to deliver their assessment activities online, each college is developing or buying assessment system or tools based on its specializations and courses. This has caused some universities to have more than one computer-assisted-assessment system. In this paper, a service-oriented e-assessment system will be suggested to solve this problem. A service-oriented architecture for a generic and flexible assessment system will be provided with cross-domain use cases to show the flexibility of this architecture.**

Keywords- E-assessment, Modular assessment system, Assessment services, Service-oriented architecture for assessment, Middleware for tools interoperability.

I. Introduction

The breadth of the assessment field and it's richness of several application domains raise problems when it comes to develop tools to assess those application domains. Numerous commercial and academic assessment systems and tools are used to assess different application domains. The level of coordination between those systems and tools highly depends on the standards and specifications underpin them as well as the domain related activities. In e-assessment design and development, the new developed tools should have the ability to communicate and interact with the existing ones without further modifications. Such tools should not be tightly coupled to a specific assessment system. Rather than, they should be reusable and interoperable so that they can be used to extend other systems and tools.

In the world of Service-oriented Architectures (SOA), the new developed services hold great promise when they are interoperable and fit with existing tools' services. One promising area is to modularize e-assessment systems in a way of composing loosely coupled assessment tools together. Such composition requires: i) clear guidance represented by a well-formed *framework*; ii) *standards and specifications* that represents the whole process of assessment as well as the communication between the services and components; iii) *cross-domain requirements* analysis in order to define the specific requirements for each application domain (such as, educational editor in the mathematic domain); iv) *web services* that provide the cross-domain requirements and interact through well-defined interfaces.

The rest of this paper is organized as follows: Section 2 explores the different aspects for understanding the e-assessment domain. Section 3 suggests a Modular Assessment System for Modern Learning Settings (MASS) towards a generic and flexible assessment system. A SOA-based architecture for MASS is discussed in Section 4. Section 5 discusses how this SOA-based architecture can be mapped into system components as part of more detailed architecture. Problems and challenges for aggregating domain-based tools and services within MASS context are discussed as part of a suggested Middleware in section 6. Section 7 investigates the MASS suggested architecture using a persona-based use case. A conclusion and future work are provided in Section 8.

II. E-Assessment domain

Challenges that may face e-assessment development varies according to the level of assessment domain understanding. Bloom's described the assessment process based on the learning outcomes represented by levels of learning objectives [1]. Authors of [2] classified the learning assessment domain into four assessment types *summative, formative, diagnostic, and self-assessment.* Some others believe that there is a need to develop models for exploring and defining this domain [3]. For Instance, the Joint Information Systems Committee (JISC) has initiated a service-oriented based framework for e-learning called "e-Framework" [4]. Based on this framework JISC has presented an e-Framework Reference Model for Assessment (FREMA). FREMA represents an intensive guide for the assessment domain resources *standards, projects, people, organizations, software, services, and use cases.* FREMA structure is based on concept maps describing the ontology that has been used to model the assessment domain. [5].

Other researches described the assessment domain from different perspectives. As in [6] the requirements for what they called the 'Ultimate' assessment engine have been discussed. From this perspective, the assessment domain has been investigated as the possible requirements for the possible stakeholders and roles of the assessment system.

A different way of domain understanding has been discussed in [7]. In this research the authors investigated the e-assessment domain as a set of possible services. A Service-Oriented Framework for Assessment (SOFA) has been initiated as a set of layers: *User Agents, Assessment services, Common Services, and infrastructure resources*. In presenting this framework they provided people in the domain of e-assessment with a guide to understand the interactions between the domain users and the available resources as a set of services. They also stressed on the importance of designing those services to be standard-conform to avoid having a repository of useless services. Rather than, those services will be interoperable and useful for designing flexible assessment systems.

III. MODULAR ASSESSMENT SYSTEM FOR MODERN LEARNING SETTINGS (MASS)

Based on the highly demand for having a generic and flexible e-assessment system, MASS has been suggested. MASS is supposed to have: (a) *flexible design* to be used as a stand-alone system or to be easily extended by third-party tools. (b) *User-friendly interfaces* for both students and educators where a user interaction and online submission of solution and evaluation can be done. (c) Assessment environment for *various learning and assessment settings* which supports guided as well as self-directed learning. (d) *Management and (semi-)automatic support* over the entire assessment lifecycle (exercises creation, storage and compilation for assessments, as well as assessment performance, grading and feedback provision). (e) *Rubrics design* and implementation interfaces to allow the educators to design their own rubrics based on learning objectives to assess learners' performance against a set of criteria. (f) *Support of various educational objectives and subjects* by using various tools sets which for example enables automatic exercise generation or selection, automatic grading and feedback provision. (g) *Results analysis and feedback provision* (immediately or timely) of the current state of user knowledge and meta-cognitive skills for both educators and learners and also for adapting course activities and learning contents based on users' models. (h) *Standard-conform information and services* to be easily sharable, reusable and interoperable. This may include the tests' questions, answers and students' results, rather than any other required services. And finally, (i) *Security and privacy* where a secure logon of users based on pre-defined levels of access, and also users' authentication based on machine (domain users) or by usernames/passwords.

MASS is planned to be a SOA-based assessment system where different assessment tools can integrate with each other to assess different application domains. MASS highly depends on interoperable web services that can extend MASS's assessment native services (Authoring, Scheduling, Delivering, Scoring, and Reporting) to assess specialized kinds of assessment (e.g. Algebra assessment and Programming assessment) based on several application domains. Fig. 1, shows how cross-domain web services can be used to extend the core services provided by MASS. A Middleware layer has been added between the Application layer and the Application Domains one. This Middleware will be designed to handle the use of domain-based web services to extend MASSs' ones for specialized application domains. Moreover, it will be used to facilitate and tackle the problems and challenges of running external domain-based tools within the context of MASS.

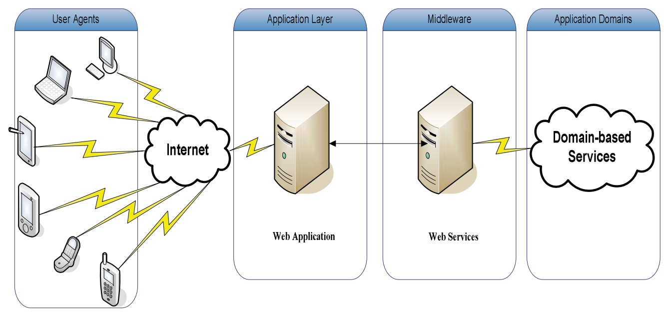

Figure 1. Cross-domain web services to extend MASS native services

IV. SOA-BASED ARCHITECTURE

As Shown in Fig. 2 a SOA-based architecture for MASS has been presented. This architecture consists of four main tiers: Client Application Tier, Business Tier, Service Tier, and Resource Tier.

A. Client Application Tier

The client application tier forms the front tier where the user agents interact with the system. Matters such as security and privacy of data and processes are handled in this tier. Furthermore, unauthorized user agents are prevented through this tier from accessing the system resources.

The **controller** of each client application must be capable of controlling the whole actions in this tier. The application processes and requests are passed by this controller to a special **interaction services** layer that communicate with the business tier using communication standards and technologies (such as Simple Object Access Protocol (SOAP), or XML-Remote Procedure Call (RPC)).

B. Business Tier

The whole business logic is taken place in this tier. In our case, the main MASS modules (Authoring, scheduling, delivering, and reporting) are part of this tier. For each module a set of core services are available in the service tier. Separating the business logic in a different tier fosters MASS to be more modular and flexible. Furthermore, this tier facilitates the update of the business logic in an easy and flexible manner. As in the client tier, this tier also has a controller and an interaction services to communicate with the service one.

C. Service Tier

In the world of SOA there are three main roles of interaction: *service provider, service registry, and service requestor.* Service providers are software agents that provide the service. They should **publish** a service description on a services registry. Service clients are software agents that **request** the execution of services. They should be able to **find** services descriptions on the services registry. The words in bold with the operation **bind** form the main operations in the SOA. During the bind operation the service requestor invokes a web service at run-time using the binding information in the requested service description to locate this service. This invocation has two main possible scenarios: the first one is direct invocation by the service requestor using the technical information in the service description located on the services registry. The second one is via a service discovery agency where the communication between the service requestor and the service provider goes through the services registry of the discovery agency. [8]. In the case of MASS the first scenario will take place where the invocation of the domain web services will be done directly through the services registry in the service tier.

In the server side there are two main operations:

- Service Registration: each service provider from the resources tier registers its web services through the **service provider interface** to the **service registry**. The service providers are normally domain related systems (such as algebra assessment system, programming assignment assessment tool…) that provide their business logic services (such as algebra marking, equation editor) as web services.
- Service Invocation: this operation is mainly handled by the **service request layer** where the requested service from the client application through the business tier modules is searched in the **core services** repository. If the service is not available in the core services repository then it will be searched in the new registered services in the **services registry.**

By using these two operations the requests from the client applications are answered. Once the business tier module (e.g. Authoring) uses a new registered web service from the **service registry** in the service tier, the service becomes available through that module **core services**. So the next time such web service is needed the module can directly use it from its **core services**.

D. Resource Tier

The resource tier contains the MASS infrastructure resources (such as MASS databases) as well as the domain related systems and tools. The domain related systems can be assessment related such as algebra assessment system or can be business related such as the Student Information System (SIS). For each of these systems and resources there are a set of web services they must provide. The more web services they provide the more flexible and generic MASS will be.

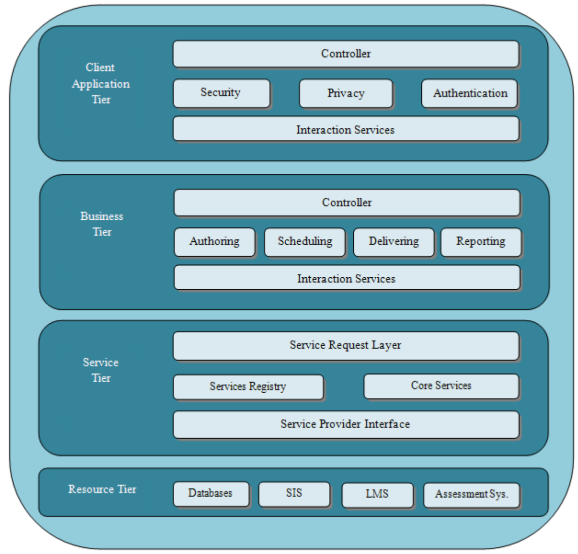

Figure 2. SOA-based Architecture for MASS

V. DETAILED ARCHETICTURE

The architecture presented in Fig. 2 is more conceptual than showing the real components of MASS. This section discusses a more detailed architecture where it explains how the SOA-based architecture layers are presented as system components and modules as well as it suggests architecture for the middleware layer. Moreover, it shows the assessment process represented by a set of core services for assessment and guided by the SOFA layers [7]. Some other common services such as authorization and authentication are also shown in this architecture. Fig. 3 demonstrates the more detailed architecture where it consists of four main layers: User Agents Layer, Application layer, Middleware Layer, and Application Domains Layer.

A. User Agents Layer

This layer represents the possible users of MASS. User agents can be native users (such as students, teachers, and administrators) or external users (such as related tools or LMSs). External users can be services requestor or provider. In case of a tool or a LMS is requesting a service from MASS, MASS should be flexible and interoperable to act like a service provider without rewriting code or system rebuilding. But if they providing services they will be part of the application domain layer and their services will be registered to the services registry in the middleware layer.

B. Application Layer

This layer represents the native components of MASS. All the assessment native services (Authoring, scheduling, delivering, analyzing or scoring, and reporting) and the common services (user management, authentication, authorization, security, and privacy) are parts of this layer. This layer can also be referred as the layer of MASS native services. Based on SOFA [7], the assessment services layer and the common services layer are mapped into modules. For instance, the assessment core services in this layer are represented by a set of main modules (Authoring, Scheduling, Delivering, Analyzing, and Reporting). The assessment process is explained using these modules by defining the main tasks of each module. As shown in the architecture of this Layer the assessment cycle starts with authoring assessments and ends with reporting. Adapting of the assessment process to achieve the learning goals is part of the analysis module. The adaptation process can suggest changes in the assessment process which may go back to the authoring services. All the communications between the assessment services are done through the services buss.

C. Middleware Layer

For the sake of generality and flexibility this layer has been added to the architecture. One of the main goals of MASS is to be flexible in order to work as a stand-alone system or to integrate with other systems and tools. This middleware forms as a run-time platform where the domain-based services (e.g. Domain-based Editor) will be registered in order to be used by MASS modules.

The domain-based services will be used to extend the services provided by MASS. As well as they will be used to integrate between MASS and other application domain systems and tools. For each new domain-based service the service provider should publish the service description on the middleware services registry. This description will be used by the MASS modules to bind the service to any possible service requestor. Moreover, a flexible design will be suggested for this layer fostering MASS to run domain-based tools as part of its context.

D. Application Domains Layer

This layer represents the systems and tools that are used in specialized application domains such as Algebra assessment and Programming assessment. For those systems and tools it is supposed that they provide their services as web services. These web services will be used to extend the MASS core services which gives MASS the ability to assess different application domains. MASS should be flexible to run those tools within its context without the need to build them from scratch. Next section discusses this challenge and suggests possible solution for that.

VI. MASS MIDDLEWARE

In order to have a flexible and generic e-assessment system the following aspects should be considered:

- Standards-conformation
- Learning Objects (LO) Interoperability
- Tools Interoperability
- User Interface Interoperability
- Web services management

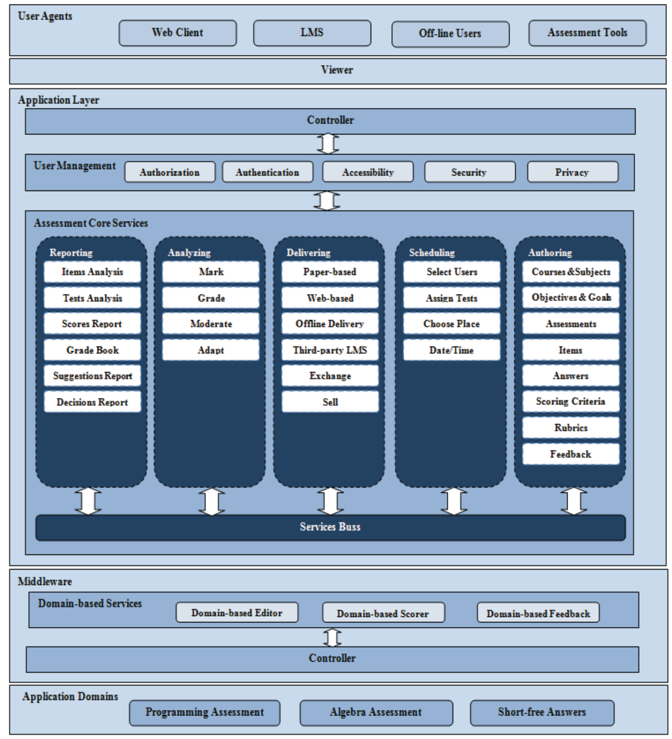

Figure 3. Detailed Architecture for MASS

In the context of e-assessment the term interoperability mainly refers to the ability of sharing Learning Objects (LO) between different assessment systems. For the sake of LOs interoperability, LOs should be standard-conform. Once they are standard-conform they can be easily shared between different standardized e-assessment systems [7]. Furthermore, these LOs can be re-used to construct new assessment activities without a need to build them from scratch. Some of the possible e-learning and e-assessment standards and specifications consortia are: The Instructional Management System Global Learning Consortium (IMS GLC) [9], Advanced Distributed Learning (ADL) [10], ADL Sharable Courseware Object Reference Model (SCORM) [11], The Aviation Industry CBT (Computer Based Training) Committee (AICC) [12], and IEEE Learning Technology Standardization Committee (IEEE LTSC) [13]. According to [14] almost all of these standards require the following aspects regarding LOs communication:

- *Launch:* the requirements for launching an LO in a web-based environment.
- *Application Programming Interface (API):* the interface of methods to be invoked by an LO to communicate with LMSs.
- *Data Model:* the dataset for the communication process.

According to [15] *interoperability* refers to "the ability of two or more software components to cooperate despite differences in languages, interface, and execution platform". Tools interoperability concerns the ability of aggregating third-party tools to cooperate with a LMS platform. Third-party tools can be used to extend the services provided by the core system with services for specialized application domains. One of the possible specifications for tools interoperability is the work provided by the IMS GLC. IMS GLC has provided an architecture for tools interoperability as web services. IMS Tools Interoperability Guidelines v1.0 has described this architecture as well as its main components [16]. The suggested architecture has introduced two main concepts:

- *Proxy Tool:* from its name this tool will be used by the LMS to communicate with the external tools. A standard mechanism for packaging this tool to be deployed to an LMS has been defined by the architecture. The proxy tool is meant to be environment-independent where it does not require specialized code. The proxy tool is entirely a *descriptor-based package* that describes the deployment, configuration, and runtime context.
- *Tools Interoperability Runtime (TIR):* is a set of services that have to be implemented to the hosting environment (MASS in our case and the application domains tools). The TIR facilitates the deployment, configuration, and launching of the proxy tool. This deployment, configuration, launch, and outcome services are in somehow similar to the launch, API, and data model discussed earlier.

The communication between the TIR/Proxy Tools is handled by a *core protocol* defined for this purpose. The core protocol is based upon the IMS General Web Services (GWS) specifications v1.0 [17] which utilize XML with WSDL for defining services and SOAP for the base transport protocol.

Since the communication between the third-party tools and the core system is performed as web services some kind of web services management is required. Matters such as services provision, services registration, services invocation, and security and accessibility should be taken into consideration. Special standards and specifications can be used to represent these web services descriptions. For instance the IMS General Web Services (GWS) specifications can be used where the WSDL/XSD created files are designed to comply with Web Service Interoperability (WS-I) Consortium Base Profile v1.1 [18].

A. Middleware Functionalities

Having that MASS is standard-conform and its LOs are authored with regarding to e-learning and e-assessment standards (e.g. IMS Questions and Test Interoperability (IMS-QTI) specifications [19]), the challenge of aggregating tools within MASS services is still there. In fact, designing MASS core services with respect to standards and specifications will not fix the problem of integrating third-party tools within MASS context. For instance, some of the services provided by the application domains tools such as cross-word puzzles in the domain of Natural Languages teaching and assessment are not covered by the available standards and specifications (e.g. IMS QTI). Another example could be the requirement for domain-based assessment tools or services such as services for scoring special types of assessment items (e.g. algebraic questions). Moreover, the need for third-party tools and services is not limited to the assessment types, rather than it exceeds that to the integration services between two systems such as e-assessment system and Student Information System (SIS).

As shown in [20] SCORM has a lack in its interoperability definition. Addressing the interoperability of content packaging and the interoperability of the Run-Time Environment (RTE) is not enough to have flexible tools interoperability. The author stressed on two other important concepts for improving content interoperability: *Standardized user interface controls, and open-source of a standardized SCORM API implementation.* Launching the content in the UI with a lack of standards causes different behaviors based on the properties of the web browser such as *width, height of the browser, resizing, area of launching within the browser.* LMS developers do not follow the same programming strategies SCORM supposing they are.

In order to tackle the fore mentioned problems and challenges the middleware has been added to MASS architecture. The middleware layer will form as a platform on which aggregating runtime interoperable tools will take place. Furthermore, the registration of the domain-based web services will be handled by this middleware through well-formed interface to a service registry. The later on binding of these services to the service requestor (MASS User Agent) is also done by this middleware. Designing this middleware in a flexible way will foster MASS to be more and more flexible.

B. Middleware Architecture

Fig. 4 shows the main components of MASS middleware as well as the required services and communication patterns with the Application Domains Tools. This architecture is highly designed based on the architecture provided by the IMS Tools Interoperability Guidelines. Based on these guidelines the following steps will take place in the deployment of the Proxy Tool:

1. *Tool developer creates Proxy Tool deployment package. The deployment package is an archive contains a manifest and Proxy Tool's deployment descriptor.*
2. *MASS administrator deploys Proxy Tool deployment package to the MASS container.*
3. *MASS TIRs deployment service loads the Proxy Tool, thus creating a Proxy Tool Definition within MASS (during which validation of the deployment profile occurs, including a validation of profiles like security, outcome, user and delivery context asserted by the Proxy Tool deployment descriptor. MASS administrator can choose to not deploy the Proxy Tool if it does not support the required profiles).*
4. *MASS Administrator configures the Proxy Tool for use within an Institution by updating its definition appropriately with MASS data model.*

5. *An instructor or course designer utilizes the Proxy Tool definition to create a Proxy Tool Instance within a delivery context (course). The instance inherits the full base configuration and is additionally customized by the instructor/designer for launch from within the specific delivery context.*
6. *A learner in the course of a learning session is presented with the Proxy Tool instance (as a Learning Object or as part of one) and subsequently launches the Proxy Tool by selecting the URL provided by the MASS's user interface.*
7. *Tool's TIR validates and accepts launch in collaboration with the MASS's TIR which directs the user to the Tool's user interface, e.g., a redirect to a Tool specific URL.*
8. *Learner uses the Tool and in doing so potentially generates an outcome.*
9. *Tools' TIR sends the outcome to the MASS's TIR at the end of a learner's interaction with the Tool.*

A possible enhancement for this procedure could be the registering of the Tool's service after the end of step 9 in the services registry located in the MASS middleware. The Tool's Service description as well as the service endpoint represented by the service URL can be published to the service registry so that in future requests the service will be directly provided to the learner or to the instructor user interface.

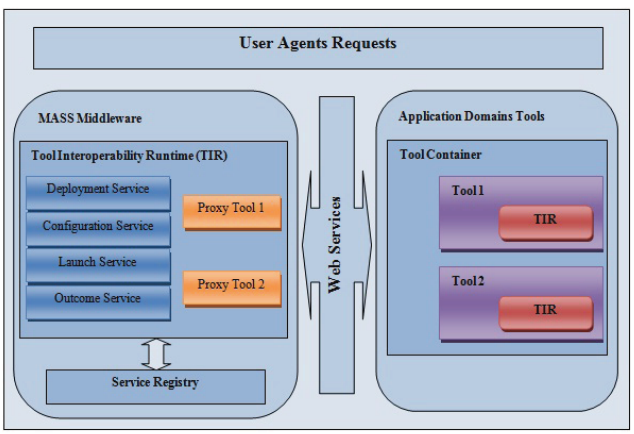

Figure 4. The cooperation between MASS modules and Application Domains' Tools through MASS Middleware

As shown in this architecture the Tool Interoperability Runtime services are:

- *Deployment Service*: The main function of this service is to interpret and load the Proxy Tool definition into the host TIR via its deployment descriptor. Thus this service is also expected to perform validation of the Proxy Tool settings in order to ensure correctness of and compatibility with the MASS's TIR.

- *Configuration Service*: The main function of this service is to manage the runtime settings of the Proxy Tool in order to provide the proper set of the same response for/during any given launch context.

- *Launch Service*: This service provides two main services, depending upon the context:

    - *Proxy Tool Host*: Performs all the functions related to launch of a Proxy Tool, including generating the relevant Proxy Tool launch message, utilizing the appropriate security profile, etc.

    - *Tool*: Exposed as a web service (Proxy Tool 1 and 2) that accepts launch messages from the MASS's TIR, understands the security profile used therein and responds back to the MASS's TIR using the Proxy Tool core protocol as to the status of the launch.

- *Outcome Service*: This service provides two main services, depending upon the context:

    - *Tool*: A web service client that generates outcome messages from the Tool's TIR conforming to a specific outcome profile type, for a given interaction of a user with the Proxy Tool/Tool, including utilizing the appropriate security profile.

    - *Proxy Tool Host*: Exposed as a web service that accepts outcome messages from the Tool's TIR, understands the security profile used therein and responds back to the Tool TIR using the Proxy Tool core protocol as to the status of the outcome processing.

VII. USE CASE

In order to investigate the eligibility of MASS suggested architecture, this section will discuss a use case of a programming course for beginners lecturer based on the following persona:

Persona, Jordi
Jordi is a lecturer at a department of computer science. One of his courses is "Programming for Beginners". For each semester a number of at least 500 students are attending this course from different departments and colleges. His department is using MASS to manage their online-assessments.

Scenario
"*I am using a programming assessment tool with simple functionalities of code-peer-review and feedback. This tool allows the annotation of code examples from students by tutors. Then the students have to annotate their pre-annotated examples. The students' annotations are compared with the tutors' ones and a valuable feedback is*

provided. I want this tool to be integrated with MASS in order to allow the only registered students in the course to upload their assignments to MASS and then those assignments will be used by the code-peer-review tool within the environment of MASS. ”

Based on this persona and scenario the following procedure will take place to integrate the code-peer-review tool with MASS:

1. Jordi registers to MASS users as a lecturer which will allow him to create the course of “Programming for Beginners”.
2. The students register as MASS users with the role students and request participation-confirm from Jordi to participate in the course.
3. After accepting students, Jordi creates a new assessment activity with type assignment using the Authoring module of MASS. As this assignment is using an external tool Jordi has to ask MASS administrator to integrate the tool with MASS resources.
4. Assuming that this tool has a Proxy Tool Deployment Package, the administrator deploys this package to the MASS container. MASS TIRs deployment service loads the Proxy Tool, thus creating a Proxy Tool Definition within MASS. If not the administrator has to ask the Tool developer/ Supplier to provide a Proxy Tool Deployment Package.
5. The administrator configures the Proxy Tool to fit with MASS data model and grants a privilege for Jordi over it. After that this tool will appear in the resources of the Authoring module used by Jordi to create the assignment activity.
6. Jordi utilizes the Proxy Tool definition from the Authoring Module resources to create a Proxy Tool Instance within the assignment (delivery context). The instance inherits the full base configuration and is additionally customized by Jordi using the Authoring module of MASS for launch from within the assignment.
7. Students who are participating in the assignment activity will launch the Proxy Tool by selecting the URL provided by the MASS’s assignment user interface.
8. The code-peer-review tool's TIR validates and accepts launch in collaboration with the MASS’s TIR which directs the student to the tool's user interface.
9. Students use the tool and in doing so potentially generate an outcome.
10. The code-peer-review tool's TIR sends the outcome to the MASS's TIR at the end of a student's interaction with the tool.
11. The outcome is passed to the MASS modules for further processing for instance to the Reporting module to provide feedback about the student-tool interaction.

VIII. CONCLUSIONS AND FUTURE WORK

According to the breadth and depth of the assessment application domains, several academic and commercial assessment tools and systems have developed. Some of these assessment tools and systems are limited to specific application domains. Moreover, they are not carefully designed to be standard-conform as well as they barely coordinate to other tools and systems in different application domains of assessment. This has caused universities and higher education institutes to have more than assessment tool. Managing several assessment tools are money and time consuming as well as requires extra resources. Tackling such problems and challenges by having a generic and flexible assessment system is a great challenge. Aggregating tools from different assessment application-domains in order to have a single flexible and generic assessment system requires: *Framework* for domain systems and tools development guidance; following *Standards and Specifications* that will help developers in producing their systems and tools; *Cross-domain requirements;* and *Web services* achieving those requirements.

A Modular Assessment system for Modern learning Settings (MASS) has been suggested as a generic and flexible e-assessment system. For the sake of flexibility and generality a SOA-based architecture for MASS has been designed. The design of this architecture is done with the guidance of the SOFA framework for assessment. The SOA-based architecture has been mapped into a more detailed architecture with a clear view of MASS components and modules. The detailed architecture has four main layers of: User Agents Layer, Application layer, Middleware Layer, and Application Domains Layer.

General and flexible assessment systems are capable to share their components with other systems. Therefore, MASS should be standard-conform in order to easily share its components. Following standards lacks a clear view of how to develop interoperable assessment tools. This lack has caused by having different standards and specifications (such as SCORM RTE, IMS TI) that have been published to support developers for developing interoperable assessment tools with weak definition for the interoperability process. For instance, in the case of SCORM RTE the standard explained how content packages conforming to SCORM standards can be shared between tools during their run-time but, it did not carefully explained launching this content in the user interface [20]. In order to facilitate tools interoperability during MASS runtime, the middleware layer has been suggested. The Middleware layer will form as a platform for tools runtime interoperability as well as for content sharing. Moreover, the middleware architecture is supposed to facilitate the domain-based web services registration to MASS. Those web services will be used to extend the capabilities of MASS native services assessing different specialized application domains.

For future work, the first prototype of MASS will be developed. A set of application-domains tools will be selected to extend MASS services. The first prototype side-by-side with the selected third-party tools will be used to evaluate the suggested architecture of MASS.

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Session 03C Area 4: Rethinking Pedagogy in Engineering Education - Multidisciplinary issues

Impact of Learning Experiencies Using LEGO Mindstorms® in Engineering Courses

Delgado-Kloos, Carlos; Fernández Panadero, Carmen; Villena-Román, Julio

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Competencies for Informatics Systems and Modeling. Results of Qualitative Content Analysis of Expert Interviews

Magenheim, Johannes; Nelles, Wolfgang; Rhode, Thomas; Schaper, Niclas; Schubert, Sigrid; Stechert, Peer

University of Paderborn (Germány); University of Siegen (Germány)

Introducing multidisciplinary thinking in Computer Engineering - A new way of teaching database systems

Baumann, Peter; Jucovschi, Constantin; Medeiros, Claudia Bauzer

UNICAMP (Brazil); Jacobs University Breme (Germány)

Engineers and their practice: a case study

Figueiredo, José; Williams, Bill

Setubal Polytechnic (Portugal); Technical University of Lisbon (Portugal)

Impact of Learning Experiences Using LEGO Mindstorms® in Engineering Courses

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Abstract— **It is well known by the educational community that active learning has a greater impact on the effectiveness of the learning process than other methods. It has long been recognized that the most effective learning techniques involve direct, purposeful learning experiences, such as hands-on or field experiences. In particular, computer-controlled models have been a useful aid in teaching programming, Artificial Intelligence and Robotics concepts. This paper describes our experience using LEGO Mindstorms® in three different scenarios: an elementary course on Programming, an advanced-level course on Artificial Intelligence and a third first-level course on Robotics. Our focus in those experiments is not on whether using LEGO kits is better than other methods to learn a programming language, AI algorithms or Robotics, but rather on introducing how this mixture of collaboration, competition and peer learning in a laboratory environment helps the students to increase their motivation and improve their professional skills such as problem solving, team work and leadership.**

Keywords: Active learning; LEGO Mindstorms; learning experiences, engineering courses, evaluation; assessment; surveys; empirical results; Java programming.

I. INTRODUCTION

After years of compelling research on the field, it is commonly agreed that the most effective learning methods involve direct, purposeful learning experiences, such as hands-on or field experiences. This fact is illustrated, for instance, by Dale's cone (Fig. 1), where passive learning would cover those activities that people can learn from, but not generally as effectively as active learning, which would include those activities that boost our learning experience.

Furthermore, active learning is even more required in technical studies (such as engineering), in which obviously concepts studied in class must be put into practice in different scenarios so that the students fully understand the fundamentals and also acquire the necessary competencies to apply them to solve real-world problems. Markets demand that professionals are mastered not only in a specific knowledge domain, but also in professional skills [2],[3], such as leadership, team work, autonomous and collaborative learning and management of increasing amount of information in short periods of time.

On the other hand, the European Higher Education Area (EHEA) [4] is investing a huge effort to foster the conversion of former ways of teaching into a modern type of learning. This new learning paradigm must be student-focused, holistic and comprehensive, helpful and encouraging, promoting autonomy and proactiveness, able to increase the student's motivation and disposition towards the course and thus improving the outcomes of the learning process. Apart from the competences specific to their curriculum, the integral vision of the learning experience is assumed to produce better qualified professionals. These professionals must have high added-value essential transversal (non-technical) competences that achieve the highest probability of success whether in current or further studies or their professional life. Team-work, communication skills and critical analysis are essential outcomes.

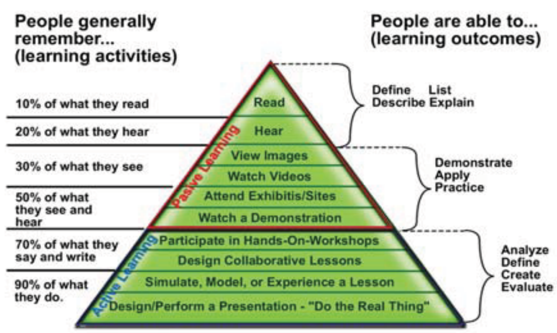

Fig. 1: Dale's cone [1] (released under a Creative Commons License)

This paper describes a series of experiments using LEGO Mindstorms® [5],[6] that have been carried out since 2005 in several scenarios involving a variety of student groups and course levels.

The purpose here is not to discuss the appropriateness or disadvantages of using those kits to teach technical topics, but rather to show how they increase motivation and improve professional skills. Activities that involve a mixture of real-world application of technical concepts, collaboration, competition and peer learning in a laboratory environment, achieve excellent outcomes in terms of students' motivation and development of transversal skills, and also improve their disposition towards hard tasks and their perception of the learning process quality. A critical analysis of how the methodology affects the learning experience is done, considering both subjective and objective results.

This work was partially supported by Learn3 (Plan Nacional de I+D+I, TIN2008-05163/TSI) and by Universidad Carlos III de Madrid (UC3M) on different calls for Experiences on Teaching Innovation.

We first review, in the background section, some previous experiences using LEGO kits in different environments. Then we place our work in context defining our goals with the introduction of Robotics in the different experiences. Then we discuss about our results and findings and how to use them in other context in future work. Finally we conclude about the usefulness of our experiences to improve motivation and develop professional skills.

II. BACKGROUND

Some studies [7] mention some of the conditions under which people learn properly, such as: what they learn is personally meaningful to them, what they learn is challenging and they accept the challenge, what they learn is appropriate for their developmental level, they can learn in their own way, have choices, and feel in control, they use what they already know as they construct new knowledge, they have opportunities for social interaction, and they receive helpful feedback. Projects using LEGO Mindstorms® have been proved as a good vehicle for implementing these concepts.

A. LEGO Mindstorms®

LEGO Mindstorms® [6] is a Robotics kit originally developed by MIT for building programmable robots. It combines standard LEGO blocks and LEGO Technic pieces (such as gears, axles and beams) [5] for its structure and a programmable brick and components (such as electric motors, sensors, etc.) for its control center (Fig. 2). The first generation of LEGO Mindstorms® was released in 1998 and was built around a brick known as the RCX. It contained an 8-bit 16MHz microcontroller with 32KB RAM. Programs written in one of several available programming languages are created on a computer and sent to the brick using an infrared (IR) interface. In addition to the IR port, there were 3 sensor input ports and 3 output ports (usable for motors and lamps) and an LCD that can display the battery level, the status of the input/output ports and which program is selected or running.

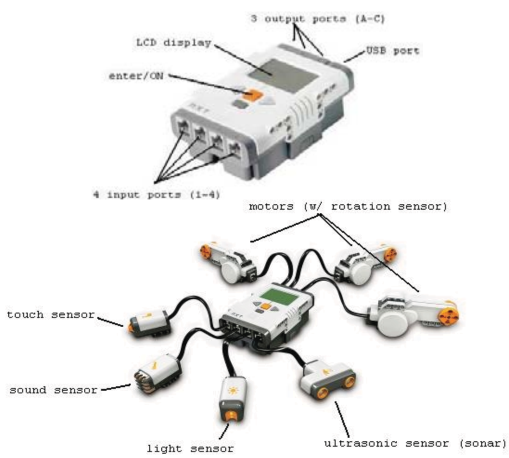

Fig. 2: Brick, sensors and actuators of the NXT kit

In July 2006, LEGO Mindstorms® NXT replaced the first-generation RCX. The new brick includes one main 32-bit 48MHz processor with 64KB RAM and 256KB Flash, and a second 8-bit processor for controlling an extended set of sensors and actuators. The brick also includes 4 sensor input and 3 actuator output ports, all of them with a digital I2C interface using a pseudo RJ12 connector. The IR interface is substituted by an USB and a Bluetooth port. The basic NXT kit consists of 519 Technic pieces, 3 servo motors, 4 sensors (ultrasonic, sound, touch, and light), 7 wires, a USB cable, a USB Bluetooth dongle, and the NXT brick. There also exist expansion kits that provide with more different building pieces and other types of sensors.

Initially the LEGO-supplied programming languages were RCX Code (assembly) and ROBOLAB (a graphical language). However, the enormous popularization of these kits led to the creation of new alternatives by the community, mainly as open source new firmware or virtual machines, supporting modern programming languages such as C/C++ and Java. For NXT, currently there exist over 30 alternatives including the Official Mindstorms SDK (Visual Basic, Visual C++, MindScript and LASM), the original ROBOLAB graphical language, leJOS (Java), NBC (assembly), NXC (C-like language), RobotC (C), GCC (GNU Compiler for C/C++, Fortran, Java, Ada, etc.), Ruby, Python, MATLAB, etc.

In general, the programming environment is simple enough to be learnt by the students easily. Thus, they can construct robots that perform complex tasks in a very short time. This combination of versatility and simplicity, together with its motivating potential, makes LEGO Mindstorms® a powerful help in a variety of learning scenarios.

B. Related work

Innovative teachers are continually looking for creative ideas, both to get their ideas across and to hold the interest of their students. With this purpose, LEGO have been widely used in different contexts with different objectives.

Fagin [8] and Schumacher [9] (2001) were among the first to introduce LEGO Mindstorms® in basic programming courses. Fagin used Ada language to teach basic control sentences (sequential, iteration or selection) and Schumacher used Java to teach fundamental computer programming concepts and introduce the concepts of autonomous vehicles, embedded computer systems and simulation. Barnes [10] (2002) also used Java and pointed out the usefulness of physical models to teach event-driven programming and the physical limitations of LEGO brick to achieve a good object oriented programming style. Wright and Gilder [11] (2003) explored the use of LEGO Mindstorms® in more advanced courses to design interdisciplinary senior projects to better prepare graduating students for their careers as engineers. His work covers robotics, algorithm state machine design, assembly programming language and compiler design concepts

All these previous work describe experiences with few students per course. Cliburn [12] (2006) reviews previous experiences and deploys a more ambitious one using LEGO Mindstorms® in 5 different courses during several years. As a conclusion of his work, Cliburn identifies three principles to consider to successfully designing these kinds of experiences. First, the project and the programming interface should support the objectives of the course and be relatively straight forward to learn. Second, the group size should be small to ensure that all students develop the required programming skills. The third principle is that students should be given time in class for building the robot. More recently, Jipping [13] introduced LEGO robots to teach Java bytecode (2007) and Talaga [14] (2009) to teach Artificial Intelligence (AI). LEGO was not only used to teach programming skills in different languages or AI techniques but also it has been used to develop professional skills [12] such as the experience proposed by McGoldrich [15] to improve peer learning or Barak's experience [7] to develop problem solving skills. All these studies reveal that using LEGO Mindstorms® in enriched collaborative learning environments has positive impact on student performance and motivation in most of the courses.

Comparing our work with previous work in this area, our main contribution is that our experience is not a punctual pilot one, but rather several courses in different context during a long period of time. We describe our experiences, like previous studies, but we also provide empirical data that support our conclusions gathered from different methods (direct observation, interviews, surveys, etc.). We also tackle the challenge set by previous work that suggests the need to collect data on how the student perceives this type of learning and research on how informal learning takes place in collaborative and competitive environments. Our findings are independent of age, cultural heritage and personal interest of the students.

III. OUR EXPERIENCE USING LEGO MINDSTORMS®

Based on those previous experiences about the benefits of using LEGO to improve students' motivation, we decided to organize a workshop that consisted of a competition where the goal was to build robots that participated in different challenges. The competition was a team-league that took place in different sessions. Each of these sessions presented challenges of increasing difficulty covering different aspects of programming, robotics and AI algorithms. The duration of the session, the difficult of the challenge and the main issues involved (programming, robotics or AI) was based on the context of the course. Work was done in teams of 3-5 students.

This was in 2005 as part of an advanced level course on AI (experience I, 33 students). The experience was so successful that we decided to carry out a more ambitious project introducing LEGO kits as an optional activity for students in an elementary course in programming (experience II, 127 students), in 2006. Most of the data analyzed in this paper was collected in this second experience. We finally had the opportunity to carry out a third similar experience in an introductory course in Robotics (experience III, 24 students).

A. Experience I: AI Course

1) Context

Our first experience with LEGO kits started in 2005, when they were introduced in a course called Intelligence in Communication Networks (ICN) [16] (first semester, fifth year, Telecommunication Engineering). Students learn the fundamentals of AI, the impact of intelligent behaviours in information systems and the areas where these technologies may bring the most significant advances. The course is elective and involves around 45 hours/semester. Sessions with LEGO typically take place during 6 sessions within regular classes (9 hours in all). These activities have the same impact on the final grade as other assignments. The experience began in 2005-2006 and was so successful that it has been repeated annually until the present. We started with 7 RCX kits but we switched to NXT kits two years later, when 20 new kits were acquired.

2) Objectives

The introduction of LEGO kits in this course was partly motivated by a significant decrease in the number of students enrolled in the course during the academic year 2005-2006, when the average of 50 students enrolled per year abruptly decreased to 33. Despite other causes (such a general decrease in the number of students at university), we think that it was necessary to introduce new lab sessions in the laboratories that motivate students while practicing their newly acquired knowledge on AI applied to Robotics.

3) Challenges

Different AI techniques, among the topics explained during the course lectures, have to be applied to solve the different challenges, such as problem solving or kNN (k-Nearest Neighbour algorithm). This way students can develop and experiment these techniques applied in a real working system. Our experience shows that at the end of each session practically all teams were able to develop a robot that meets the specifications stated in the challenge.

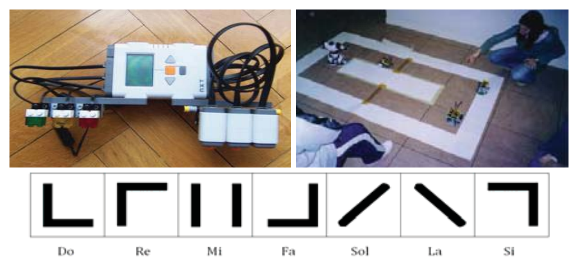

Fig. 3: Challenges in ICN course

In addition to an introductory session, three main challenges are posed to the students (Fig. 3):

- **Rock, paper, scissors**: Build a smart robot able to play that game. The purpose is to illustrate that most times an intelligent behaviour can be implemented with common-sense rules.
- **Escape from maze**: Build a robot able to run away from a maze. This task needs more advanced planning and solution search techniques.
- **Artificial vision:** Build a robot able to recognize and classify images. In this case, the aim is to implement a classifier using any of the studied techniques.

4) Methods and Results

The mixture of robotics, competition and collaboration reveals itself a powerful combination for learning AI. The students were highly motivated for this kind of lab sessions. The initial objective to increase the number of students enrolled in the course was reached as it can be seen in Fig. 4.

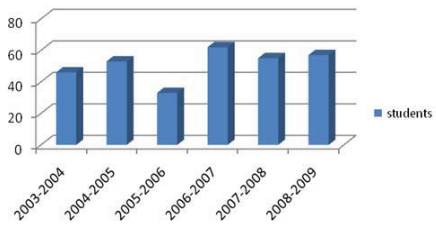

Fig. 4: Evolution of number of students enrolled in ICN course

As a collateral result, a significant increase in the number of Master's Thesis (Fig. 5) was achieved.

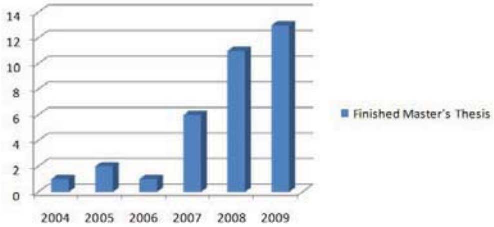

Fig. 5: Finished Master's Thesis supervised by the authors

This increase was mainly due to students who had been enrolled in ICN course, particularly in thesis about topics related with ICN contents, as shown in Fig. 6.

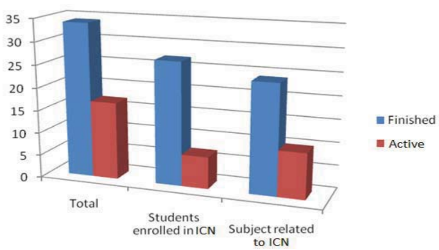

Fig. 6: Master's Thesis supervised by the authors related to ICN course

Annual teaching evaluation surveys show that the main reasons for choosing the course are the appealing syllabus and express recommendation from students of previous years. Although the relatively high passing rate could also influence the choice, we think that it doesn't constitute a key factor as this rate is similar to other subjects.

B. Experience II: Programming Course

1) Context

After this first successful experience in the first semester, LEGO kits were also introduced in four different introductory programming courses [17] taught in first year of different degrees, as an optional workshop at the beginning of the second semester, named Robot.IT![1] [18]. The experience began in 2006 with a pilot group of 127 students enrolled in these different degrees. The distribution of students by degree, in that academic year was the one shown in Fig. 7.

[1] IT stands for *Ingeniería Telemática*, our Department.

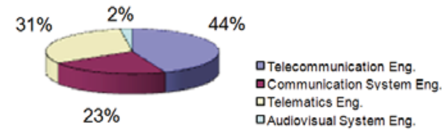

Fig. 7: Distribution of students by degree (2005-2006)

In this case, the workshop deployment has a significantly higher management cost than in the first experience, mainly due to the high number of participants. For this reason, the workshop is not organized on an annual basis but once every two years, giving the opportunity to join to students who enrolled in the subject that year and the year before.

2) Objectives

Programming courses during the second semester deal with algorithms and data structures (stacks, queues, trees, etc.). Students enrolled in these courses have previously received teaching during the first semester, on basic programming structures and object-oriented programming concepts. In general, results achieved by students during the first semester usually are not very good, and many students leave the course even before lectures start in the second semester. After the disappointing first semester results, it was necessary to influence student motivation to increase attendance of students enrolled in lectures and labs during the second semester.

The decision to introduce LEGO kits in those courses was largely motivated by the success achieved on our previous experience. Our main goal was to stretch the motivation gap between the first and second semester and to get student excited again about learning programming. To reach this goal we provide a different and enriched competitive and collaborative learning environment that fosters general interest in programming and illustrates the usefulness of programming in computer controlled physical models. Aside from the programming aspects, this environment also provides nice illustrations of two fundamental concepts that are often associated with Java: bytecode portability and the programmability of small devices as we mentioned above.

Our objective was not to improve student performance in courses, since the contents taught in the workshop had no direct relationship with those seen in class. For this reason the workshop was optional and has no impact in the final grade. The workshop takes place during 3 sessions outside regular classes with a total duration of 9 hours (3 hours per session).

During the workshop a teacher and a set of teaching assistants (typically two per session) help teams to resolve any doubt or technical problems. Teaching assistants are students chosen from among the course participants who have volunteered for this work. The teaching assistants have a short preparatory session with the teacher before the start of the workshop where they are trained in the tasks to be performed and the difficulties that arise in each session to be able to support their peers.

Finally, the large number of students involved in this second experience allows us to take some measures in order to evaluate the real impact of the workshop on student motivation and asses the methodology used during the experience. Issues related with the duration of each session, the number of sessions, the worst and the best aspects of the workshop, etc. were measured.

3) Challenges

Three challenges were posed to the students:

- **Robot Sumo Fight**: Build a robot that plays an all-against-all sumo tournament, pushing all the opponents out of the game area. This is a basic challenge to learn about light sensors and practice loops and conditionals.
- **Robot Recycler**: Build a robot able to find as many soft-drink cans as possible, pushing them out of the game field in one minute. This challenge involves several sensors and, optionally, advanced search strategies based on an ultrasonic (sonar) sensor.
- **Line Tracker**: Build a robot that can follow a path, a black line on a white surface, in the shortest time. This is a typical example of a non-trivial rule-based system.

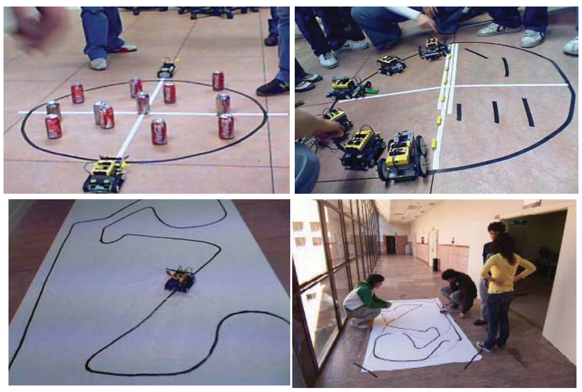

Fig. 8: Robot.IT! workshop

4) Methods and Results

A 40-question survey was designed to calibrate and improve some issues related to the **learning design** of the workshop, gather student opinion about the workshop **contents**, evaluate the impact in student motivation, evaluate **student's perception about his/her own learning**, evaluate the student's opinion about **using LEGO Mindstorms® in other courses**, evaluate their opinion about the **integration of workshop results in their grades**, and other questions (not related with this paper) about schedule, distribution of students by sex, how they knew about the workshop, opinion about the blog, etc. Survey has answered by 98 out of 127 participants and some conclusions can be drawn on each issue.

a) Results about the learning design of the workshop

- **Schedule**. Students agree with the session length (Question 19). 59% would keep as they are (3 hours), 37% increase in 1 or 2 hours. Only 4% of respondents would reduce the length of the sessions. Most people (82%) think that the difficulty of the challenges is adequate for the available time (Q20, Fig. 9). As each session was an independent challenge, we conclude that 3 hours is an appropriate time to address each of the challenges. In general, students are highly motivated, and despite the fact that the workshop involves about 9 hours (3 hours per challenge), takes place outside usual teaching hours and has no impact on the grades, surprisingly, most students (65%) would prefer to increase the number of sessions (Q18).

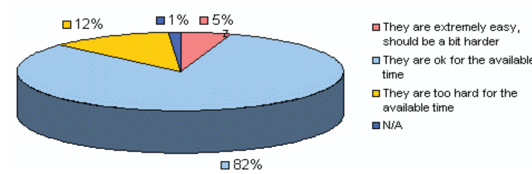

Fig 9: What do you think about difficulty of challenges? (Q20)

- **Groups**. When we asked students for the optimal group size (Q21), 59% would support increasing the group size to 4 people, 36% would keep the current suggested size (3) and only 5% which would reduce it. Despite students' opinion, our experience shows that the optimal size of groups is 3 persons because the pressure on the three members is just to keep everybody working. Increasing the pressure is likely to not complete the challenge and if the pressure decreases, there is a risk that some members do not work enough and the rest have time to absorb his work.
- **Teaching assistants**. Students highly value the presence of teaching assistants in class to support them during the session (Q23). 80% consider them a great help to overcome the challenges. Regarding whether they prefer to deal with the teaching assistants or teachers (Q24, Fig. 10), 61% prefer the teaching assistants because they are students and their relationship is closer. After the experience 30% of students would enrol as a teaching assistant in future editions.

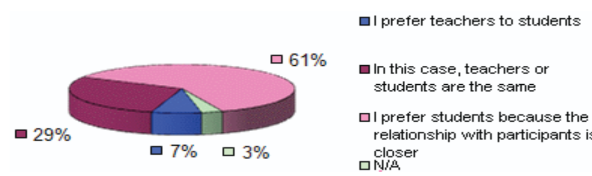

Fig.10. Do you prefer teacher or assistant support? (Q24)

- **Competition**. Most of the students (74%) consider the competition among groups highly motivating (Q30, Fig. 11). and 95% of the students agree in the importance of the competition factor in the workshop.

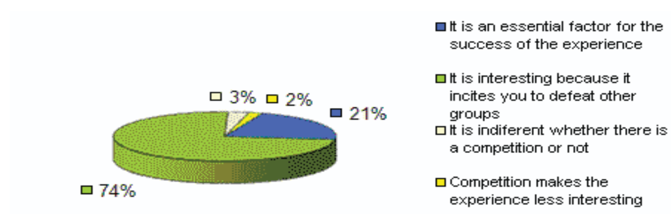

Fig.11. What do you think about the competition among groups? (Q30)

- **Preparatory work**. In order to analyze if preparatory work was necessary, we asked the students if previous lessons would have been interesting to improve the experience (Q16). Most students (56%) said it was not necessary since they could learn by themselves. 30% considered interesting to receive a previous lab class and 12% a previous lecture.

- **Students' preparatory work**. As previously mentioned, documentation for each challenge was provided at least a week in advance, and students were suggested to review it. When the students were asked if they prepared the sessions in advance (Q28, Fig. 12), most people (64%) answered negatively, and 60% said that they spent no time in preparing the sessions (Q29, Fig. 13). Despite the poor students' previous work, all the teams reach the challenges goal at the end of each session. We think that this lack of commitment from students is also because the workshop was conducted outside school hours and had no impact on their grades. When we asked what it would have happened if the workshop was a course for itself (Q31), students said they would have studied how to program the robot (62%), how to build the robot (5%), or the strategy to win the challenge (32%).

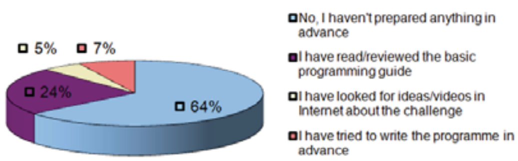

Fig. 12: Have you prepared the sessions in advance? (Q28)

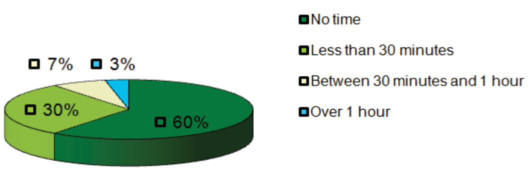

Fig. 13: How long have you prepared the session in advance? (Q29)

b) Results about content

- **Preferences**. When we asked participants which tasks they liked most (Q12), almost half of students (45%) responded that all of them in general, 26% preferred the work related to building the robot, 22% chose the hardware and software strategy design to solve the challenge, and only 7% preferred programming tasks. On the other hand, when they were asked for the most unpleasant tasks, half of the students (50%) answered that all of them in general, 25% dislike to write the control program, 11% to build the robot and 10% to design the strategy. We conclude that there is not a very marked preference for one kind of task with respect the others. 45-50% of the students do not manifest any preference. One of the most disliking tasks is programming in Java (25%) because it is one of most difficult task for them, as will be seen later.

- **Difficulties**. Tasks that are more difficult for students (Q14) are related to the integration and testing of the robot (43%) but these are not the ones they dislike. The next task by difficulty level would be programming (35%) and building the robot (17%). Although programming is considered by the students as one of the most difficult (35%) and disliking (25%) task, it is also considered the most important factor to win the challenge (53%) followed by good luck (30%) and building a mechanically good robot (13%).

- **Documentation**. Most of the students (55%) think that the documentation could be improved introducing more code examples (Q22). This issue has been solved in subsequent editions.

c) Impact of the workshop in student's motivation

- **Reasons to enrol**. When students were asked about why they took part in the activity (Q9), the two main reasons were to learn something about robotics (53%) and as a recreational activity (36%).

- **Subjects involved in workshop**. After the experience, students showed more interested in Robotics (Q37). 58% wanted to study more about this topic. Also they showed more interest in Java (Q38): 56% think that they liked programming more, and 44% kept the same opinion than before the workshop.

- **Overall opinion**. The general opinion about the experience was very good (Q10, Fig. 14) and 100% would recommend the experience to a friend (Q11). To calibrate their interest in the workshop, they were asked, as a kind of joke, what their response would have been if they would have had to pay to get better prizes (Q40). Surprisingly they would pay from the workshop. Most of the students (45%) would have participated for 3 €, 17% for 1€ and 23% for 5€.

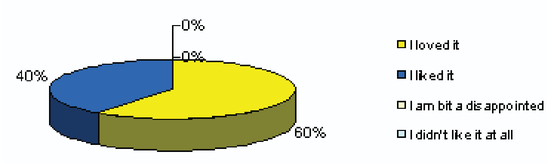

Fig.14: What is your opinion about the experience? (Q10)

d) Perception of the student about their own learning

- **Previous knowledge**. Only 5% has previous knowledge about LEGO kits (Q6), the rest (95%) had no knowledge before starting the activity. Regarding their self-perceived knowledge of Java (Q7), although all of them have a previous course in Java during first semester, in general (58%) their previous knowledge was not very high.

- **Knowledge about robotics**. 98% of the students say that they have increased their knowledge about Robotics. 58% also say that, as a result of the experience, they are more interested in Robotics than before (Q37).

- **Knowledge about Java**. Their perception of learning Java is lower than learning Robotics (Q35). 47% of the students answer that they have learnt about Java, but surprisingly, within this group, 32% felt that concepts learnt were not useful in their degree. In fact, we anticipated these results, because the content of the workshop was not directly related with the content of the programming course as it was mentioned before. Then students were asked about what they would change in the workshop so as to be able to learn more Java (Q36). Only 6% think you cannot learn Java using LEGO. The rest report that it could be useful to have a lecture explaining useful programming techniques (41%), others prefer to have more difficult challenges that need advanced techniques (24%), and finally others chose to have the same challenges, but forcing certain programming techniques (28%).

e) Integrating the workshop in their grades

When students were asked about their opinion if they have to grade the experience (Q31), 10% thought that it should be based on the ranking of the competition, 32% of the people report that the grades should be based on the quality of the robot and the degree of fulfilment of the challenge requirements, 45% thought that there should be a balance among those criteria and only a 18% report that the grades should be based on the evaluation of the robot by the teachers.

f) Using LEGO Mindstorms in other courses

After the workshop, most of the students (94%) report they would like to have some workshops like this in their studies (Q33). In this group, 29% would like to integrate this experience regardless of evaluation criteria, but 65% think that the evaluation criteria have to take into account not only the results of the competition but also the quality of the robot and the fulfilment of the challenges.

C. Experience III: Course on Robotics

1) Context

In the third experience, LEGO kits were specifically used in the context of a course on Robotics, included in the list of BEST summer courses. The Board of European Students of Technology (BEST) [19] is a non-profit organization that provides communication, co-operation and exchange possibilities for students all over Europe. BEST organizes different activities where students from member universities get the opportunity to increase their international experience, establish contacts, improve their English and have fun. Each course is attended by 20-30 engineering students. Participants attend lectures given by the university's teaching staff or by experts from companies. At the end of the course, students take an exam, designed to evaluate the participants' success. The title of the course was "My robot, my lovie and me" [20], took place in June 2009 and involved 24 participating students of different European countries, along with around 10 Spanish members of the organizing local committee.

2) Objectives

The decision to introduce LEGO kits in this context was motivated because it provides a different environment in which some concepts about engineering are learnt in an environment that promotes social interaction. As the course was specifically the LEGO workshop, we had the opportunity to assess the concepts taught during the sessions, without interaction of other elements such as lectures or other laboratory practice.

3) Challenges

Five challenges (Fig. 15) were posed to the students:

- **The chilling cable car**: Build a cable car able to pull itself along a string, as fast as possible.
- **The risky can recycler**: The same as the Robot Recycler challenge in experience II.
- **The impassible robot rumble**: The same as the Robot Sumo challenge in experience II.
- **The fearless cowboy**: Similar to the Line Tracker in experience II, with a higher difficulty level involving harder curves, tunnels, ramps and any sort of obstacles.
- **The grand death race**: Similar to the previous one but introducing crossovers, thus forcing robots to use more sensors to deal with this issue.

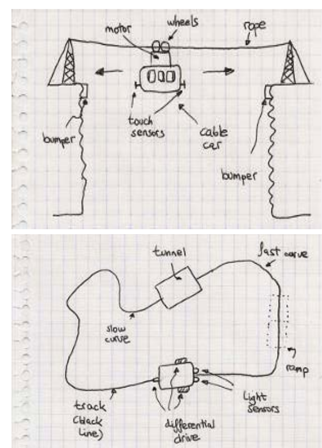

Fig. 15: "My robot, my lovie and me" challenges

4) Methods and Results

To calibrate the impact of the learning experience, an exam was carried out at the end of the course. The exam had 10 questions. Questions from 1 to 5 were about robot components and their behaviour in different situations. Questions from 6 to 10 were about programming the robot behaviour. In both cases with increasing difficulty of the first to the last question of each block. The results are shown in Fig. 16.

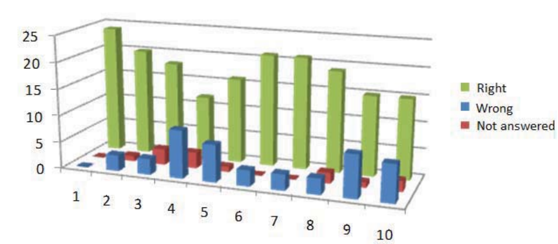

Fig. 16: Exam results in BEST Course

Student performance is high in both cases but noticeable a slight decrease in the number of questions answered correctly at the end of each block coinciding with the increase of difficulty in questions as shown in Fig. 16.

D. Informal learning and workflow

One of the most important results of these ongoing experiences developed over the last five years has been the observations gathered by the teachers and the teaching assistants who supervised the workshop. This information was directly collected by the authors during the sessions and through subsequent interviews to different participants. These observations provide valuable information on how informal learning takes place during the sessions.

One of the findings was that the workflow of the students was the same regardless of age, gender, country of origin or course level into which they were enrolled. It is also independent of the subject they were related to, whether the course was mandatory or voluntary, the result of the activity was or was not part of the final grade and even whether participants knew or didn't know each other before starting the workshop and groups formed spontaneously or as directed by the teacher. Typically the workflow was the following:

- **Understanding the goal and collecting information**. Students attend the teacher introduction and read information about the challenge (description, rules and hints). This information was available from one week before the session but students usually didn't review the material until they were directly challenged in the workshop as shown in Fig. 12 and Fig. 13.
- **Brainstorming and planning**. Then, they planned to outline the characteristics of the robot (large, small, light, heavy, number of sensors and actuators) and the general strategy.
- **Organization and division of roles**. Normally, and usually before finishing the previous stage, the students, trying to be efficient due to the pressure of the competition, begin to distribute the work among them, both explicitly (sometimes they reach an agreement on how to share out the work) or implicitly (sometimes it just happens naturally). It has been observed that there is a general tendency for women to handle more of the tasks associated with building the robot and men related to programming the brick, although this issue has to be further analyzed based on actual objective evidences.
- **Solving problems**. When first problems for each role appear, this is the typical sequence to solve them: 1) Ask team partners with other roles; 2) Review extra documentation (tutorials on building and programming robots using LEGO kits); 3) Ask teaching assistants or teacher(s); 4) Ask students in other teams with the same role.

  Some groups prefer to interact with other students rather than with the teacher, so they first ask the teaching assistants. However, the teacher usually gives a more effective technical help (especially in hard challenges), so some groups directly make this choice. In any case, we are not able to draw any conclusion because the choice can be simply based on availability (usually there is just one teacher and several teaching assistants).

  After the first round of questions, steps 3 and 4 changes the order and finally the sequence is 4 and then 3. This is because normally teaching assistants and teachers are in high demand and are slow to respond and therefore they finally prefer to ask students in other teams with the same role and similar tasks. In most cases, interacting with other teams is enough to solve the problem, and only in very specific cases the teacher support is essentially necessary, for example when the group is severely delayed with respect to others. In this phase, the main flow of information is among students in different teams with the same role, what we would call "meeting of experts".

  At this point, it is worth to notice that, although students provide information to other teams, there is no plagiarism because this help gives them clues to solve their problems, but does not provide them with the whole information that they have used because, after all, this is a competition.
- **Integration tasks**. When different roles advance in their task, they need greater interaction with teammates to integrate all efforts in the same direction because there are strategic decisions that heavily rely on work done by other members. In this stage of the work, there is an important flow of information among teammates who begin to learn about the tasks assigned to other members of their own team.
- **Testing**. Even though the students have tested their work in previous stages, during individual work, in this phase all the teammates work together to build the final result. In this stage the students learn a lot about the work developed by other teammates and all team members work together.
- **Improving performance** to be the better. At this stage, students inspect the robots developed by other teams in great detail and learn the best strategic decisions to integrate them in their own robots.

The mixture of collaborative and peer learning with a competitive environment have been proved to be a great tool to improve motivation and meaningful learning in our students.

When the students were asked about the methodology used during the session they are not always aware of the workflow followed, but the information collected by other sources shows that was the same in all experiments despite the different contexts in which they have occurred.

IV. Discussion

From the very beginning, we didn't think about these experiences as one-off events but instead as ongoing activities that we planned to repeat with a certain periodicity. In fact, once that the initial investment both in LEGO kits and accompanying material (such as sticky tape, ropes, game fields for the challenges, bridges or ramps for the track, etc.) and also in the preparation of teaching material (such as the descriptions of the challenges, the fundamentals of Robotics or AI techniques, tutorials, programming guides, hints, etc.), each new edition is less demanding and the effort for carrying it out is mainly limited to the time for arrangements (lab reservation, software installation), some cheap consumables and, obviously the teacher's attendance to the different sessions.

Specifically, experience I involving ICN course will be repeated on a yearly-basis during each academic year, at least while the current study plan is active. As shown in the result section, students' satisfaction is very high as proved by the annual course evaluation surveys and the increasing number of enrolled students, so it turns out to be a motivating factor.

Regarding experience II, Robot.IT! will continue to be a biannual activity. Here the requirements are considerably harder than in the first case, mainly because of organizational issues (for instance, sessions take place out of normal teaching hours, so we have to deal with the short availability of laboratories and constraints in student timetables) and also because they involve a high number of students.

The survey gives many details about technical issues to maximize success when carrying out activities involving LEGO kits. The results reveal that the optimum team size is three members; the session length of about 3 hours, the number of challenges depending on the available time, the difficult of the challenges proposed is adequate to the students' level of knowledge. Also the study shows that students prefer autonomous and peer learning and they prefer to be technically supported by other students than by the teachers, because the relationship with them is closer. Competition and social interaction are key issues that contribute to increase the student's motivation. Although the experience is fully satisfactory for students and increases their motivation to learn programming, the experience can be substantially improved by stretching the gap between the contents of the workshop and the content of programming courses. Our next steps will be oriented in that direction as we explain in the next section.

Finally, experience III is the least regular one, and whether there will be or not some new editions will depend on factors that are out of our direct control. However, developed materials and ideas can be easily reused in the other experiences.

To sum up, these experiences have illustrated that the participation in workshops as a form of active learning (Fig. 1) is highly motivating for students and contributes significantly to reinforce transversal skills (autonomous learning, problem solving and team work) learnt with this experience.

V. FUTURE WORK

There is still much room for improvement and there are still many new ideas to put into practice in the different scenarios.

From our point of view, in the case of experience I, the problem is that AI courses usually comprise a wide and compartmentalized syllabus covering many techniques and applications in different areas (though very briefly in some cases) that has to be taught (and learnt) in a few hours and by means of a limited short number of exercises. Interest in sessions using LEGO kits is not discussed, as students themselves think, but are in fact quite isolated. We find out that students sometimes have certain difficulties to reinforce those basic concepts or even learn them. In consequence, a major drawback of such didactic approach is that students focus on 3 or 4 topics from the entire course contents. Although deep learning of those topics is probably ensured, learning of the rest of the contents is also probably much more superficial. To overcome this limitation, the schedule has been yearly rearranged to solve some of these problems (mainly eliminating the less interesting topics for engineering students).

In another work, we proposed the application of peer review methodology [20] as a complement to the project-based learning approach in order to allow students to explore in depth other topics besides the one developed in their own projects. Preliminary results are promising, but these conclusions still have to be further studied in detail.

Regarding experience II, we want to strengthen the links among concepts introduced in the programming courses and the ones that students have to put into practice when they are programming their robots during the workshop. Our idea is to make a higher effort to improve the teaching process. First, we are interested in reviewing essential programming concepts such as different types of loops (for, while, do, until), the usage of conditionals (both isolated or inside a loop), the meaning of variables to represent a given state of an automaton, inclusion of arrays, etc. Then we would like to introduce advanced programming concepts, such as multitasking or event-oriented programming, which appear quite naturally during the challenges. In addition, we would like to give the participants and overview of advanced extra concepts related to engineering and Robotics (such as dynamic sensor calibration, basic driving techniques, degrees of liberty of a system, etc.) and/or AI techniques (such as search strategies for problem solving, rule systems, simple machine learning algorithms, etc.). We also will force the interchange of roles among team members in during each session to improve the learning of different skills.

In general, we have to catch the student attention to the workshop. Despite its attractiveness, the workshop is elective and competes against all other courses (compulsory, more important, failed from previous years...). Apart from the workshop contents themselves, there are probably many influential factors, for instance, their timetable or the academic calendar, which have to be considered globally as a whole.

Regarding experience III, no significant changes are planned to be introduced in eventual future editions of the course. However, the promotion of the course will be improved and lessons learnt from these experiences will be introduced.

In addition, a recurrent topic for us is how to foster the development of transverse abilities in students. Lacks in some basic competences are detected in students, such as idea communication, oral or written expression, critical analysis, self confidence, etc. Although this is more a continuous holistic process and the impact of these experiences is very hard to evaluate, we are interested in promoting those competences, so our plans include the incorporation of psychologists or educationists so as to research on this topic.

Finally one of the most important challenges for future editions of these courses is to integrate the conclusions drawn on how informal learning takes place during LEGO Mindstorms® workshop and introduce them in the lectures. To do this, we plan to propose enriched learning experiences, with weekly challenges to be solved by teams of three members. We will try to promote competition among teams and role interchange inside each team. We also provide material for autonomous learning and promote experts meeting among members of different teams with the same role to improve the learning, and integration meetings among members of the same team to fix relationship among concepts.

VI. Conclusions

In this paper, we have described our experience using LEGO Mindstorms® in different context in a period of five years. The originality of our study in relation to previous work is the length of the experience, the fact that it has been performed simultaneously in different contexts and the focus on the way in which informal learning takes place in these competitive and collaborative environments. We also provide a description of challenges, technical issues, parameters and references to implement this experience using LEGO. In addition, we provide the workflow description and list some lessons learnt about informal learning in order to enrich other learning environments not directly related with LEGO Robots.

We have shown the impact of using LEGO workshop in student motivation (Fig. 4). There was a 73% growth in the number of students enrolled in ICN (from 33 in 2005-2006 to an average of 57 students per class in subsequent years) as a result of introduce LEGO Mindstorms® in this course. 71% of the Master's Thesis supervised by the authors was directly related with ICN course (Fig. 5 and Fig. 6). All students surveyed (100%) would recommend a workshop like this and 94% would include similar experiences in other career courses. Measures about the benefits of competitive, collaborative and peer learning as they are perceived by the students have been taken. 74% of the students consider competition among groups a key issue to increase motivation (Fig. 11), 80% consider that teacher assistants are a great help to overcome the challenges proposed and 61% prefer asking other students rather than the teacher because their relationship is closer with them (Fig. 10).

Based on with the data collected during these experiences, we also calibrate some issues like the optimum group size, session length and number of challenges. We expect that the information provided by our experience can be useful to other groups interested in using LEGO Mindstorms® to promote active learning in their classes and maximize the success of their experiences.

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Competencies for Informatics Systems and Modeling

Results of Qualitative Content Analysis of Expert Interviews

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Abstract— **This article presents the first results of expert interviews conducted within the project MoKoM funded by the German Research Foundation (DFG). These are intended to refine our first theoretically derived competence model comprising competencies in the domains of informatics systems and modeling. In this context, the question arises, which software engineering workflows could be relevant for software engineering education at secondary schools and which are also adequate in professional contexts. Furthermore, it will be exemplarily shown which competence aspects have been added to the theoretical model and how to advance it in an empirical manner.**

General Issues in Engineering Education, Pedagogies, Modeling Competencies, System Comprehension, Active Learning

I. MOTIVATION

This article describes the methodical strategy to develop a competence model for informatics systems and modeling especially conducting and analyzing expert interviews within the project "Measurement Procedure for Informatics in Secondary Education (MoKoM)" funded by the German Research Foundation (DFG) [1]. Also, first exemplary results of the content analysis of the expert interviews are presented. Due to these results refinements on the theoretically derived model were accomplished. The article gives an outline of an exemplary analysis of 17 interview transcripts. The main focus is on the refinements of the theoretically derived competency model which could be obtained due to the results of the content analysis. Our temporary competence model was derived by means of theoretical and rational considerations. That means that curricula and expert papers treating informatics modeling and system comprehension were taken into account. However, a restriction on exclusively theoretically derived competencies would risk that the reference of competencies to complex requirements in real situations is neglected or disregarded. For this reason, an additional step is necessary in order to determine competencies more reliably, that is, ensuring an empirical access to determinate the relevant competencies. Conducting expert interviews within which the Critical Incident Technique was deployed, representing an appropriate empirical approach in order to detect the relevant competencies which belong to the two domains informatics modeling and system comprehension.

II. THEORETICALLY DERIVED COMPETENCE MODEL

In the following, the four competency dimensions of the informatics modeling and informatics comprehension model are presented.

K1. Basic Competencies

- K1.1 System Application
- K1.2 System Comprehension
- K1.3 System Development
    - K1.3.1 Business Modeling
    - K1.3.2 Requirements
    - K1.3.3 Analysis & Design
    - K1.3.4 Implementation
    - K1.3.5 Test
    - K1.3.6 Deployment

Figure 1. Competence Dimension K1 Basic Competencies

They form the fundamental framework of our theoretically derived competence model.

K2. Informatics views

- K2.1 External view
    - K2.1.1 Expectations of Systems' Behavior
    - K2.1.2 Informatics Literacy & Professional Practice
    - K2.1.3 Usability
- K2.2 Internal view
    - K2.2.1 Layered Architectures
    - K2.2.2 Net-Centric Computing
    - K2.2.3 Systems of Patterns
    - K2.2.4 Algorithms & Data Structures
    - K2.2.5 Fundamental Ideas of Computer Science
    - K2.2.6 Graphical Representations
    - K2.2.7 Languages (Programming & Modeling)
    - K2.2.8 Computational Thinking (imperative, functional, logical, object-oriented)

Figure 2. Competence Dimension K2 Informatics views

All competence dimensions were theoretically based on international syllabi and curricula with high reputation, e.g., the

"Computing Curriculum 2001" of ACM and IEEE [2], "Model Curriculum for K-12 Computer Science" of the ACM [3]. These sources gave us a lot of inspiration and concrete advice for the structuring of our competence model. We also analyzed competence frameworks with high reputation, e.g., "The European Qualifications Framework (EQF)" of the European Union [4], "Definition and Selection of Competencies (DeSeCo)" of the OECD [5]. But none of these competence frameworks are really appropriate for education in the field of computer science.

The competence component K1.2 *System comprehension* was theoretically based on "Development of Competencies with Informatics Systems" [6]. The competence component K1.3 *System development* was theoretically derived from the process workflows of the Rational Unified Process (RUP) [7]. Each dimension comprises different competency components which characterize in more detail the requirements within the two mentioned informatics domains. According to Weinert´s notion of competency [8], competencies encompass both cognitive and non-cognitive skills and abilities.

K3. Complexity

K3.1 Number of Components of Informatics Systems
K3.2 Level of Net-Centric Computing
K3.3 Stand-alone Systems vs. Distributed Systems
K3.4 Level of Human-Computer Interaction

Figure 3. Competence Dimension K3 Complexity

Whereas the first two dimensions K1 *Basic Competencies* (see Figure 1) and K2 *Informatics views* (see Figure 2) are targeted on cognitive aspects with regard to the two domains, the fourth dimension K4 *Non-Cognitive Skills* (see Figure 4) includes attitudes, motivational, volitional and social skills which are of crucial importance for managing high demands and solving informatics problems in complex situations.

K4. Non-Cognitive Skills

K4.1 Attitudes
- K4.1.1 Perception & Anticipation of Informatics Systems
- K4.1.2 Expectations for Informatics Literacy & Professional Practice

K4.2 Social-Communicative Skills
- K4.2.1 Cooperation & Teamwork
- K4.2.2 Empathy: Change of Perspectives & Roles (User, Developer)

K4.3 Motivational and Volitional Skills
- K4.3.1 Openness to new Ideas & new Requirements
- K4.3.2 Learning Motivation
- K4.3.3 Commitment

Figure 4. Competence Dimension K4 Non-Cognitive Skills

The third dimension K3 *Complexity* (see Figure 3) is chosen in order to obtain a graduation of competencies which correspond to different levels of learners' skills. Also for this reason the first two dimensions are additionally graduated according to following taxonomic levels: (1) Knowledge, (2) Transfer and (3) Evaluation.

III. Examples of Qualitative Content Analysis of Expert Interviews

A. *Procedure of Conducting and Analysing the Expert Interviews*

In a first step of the empirical procedure the expert interviews were conducted. 30 experts on informatics, with a division in three equal groups were interviewed: experts in the domain of didactics of informatics, computer scientists and expert informatics teachers. This sample configuration was chosen in order to reveal the widest possible range of informatics and didactics expertise. The interview was based on a structured questionnaire manual and included questions concerning the expert status of the interviewees and several scenarios concerning application, testing, modifying and developing of informatics systems resp. software. Altogether 12 scenarios were used in the interview. To limit the duration of the interviews to an appropriate length each interviewee was only interviewed to four scenarios. Each interview lasted about 60 to 90 minutes. The interview included the following steps: (1) Welcoming the interviewee and introducing the underlying notion of competency and the interview technique (critical incident technique), (2) Presenting each scenario to the interviewee and encouraging him or her to give details of his/her intimate proceedings and approaches to solve the presented informatics problem, (3) Asking the interviewee to evaluate the four hypothetical scenarios with regard to their representativeness (with reference to rating scales).

The expert interviews were transcribed in full and analyzed by means of qualitative content analysis according to Mayring [9]. The main objective of qualitative content analysis is to reduce the large text material to a manageable size in such a manner that important information is not wasted. *Summarizing, explicating and structuring* are the main techniques of qualitative content analysis. The first technique enables to compress extensive proportions to text material. Deploying the second technique additional text material is brought to those passages in the text which need further explanation. The third technique means that a certain structure is extracted systematically from the text material. In our case this structure was brought to the text material in the form of our category system which belongs to our theoretical competency model. Analyzing the interview transcripts, all three techniques were applied. They do not mutually exclude one another, but rather complement each other well. At first, meaning units (i.e. textual elements containing relevant information concerning competencies) were systematically extracted. In the next step, it was investigated if the gathered meaning units could be matched to the competency categories of our model.

B. *Informatics Systems*

In Section B, we focus on K1.2 S*ystem comprehension* and its relations to other competence dimensions through concentration on a typical scenario "testing of unknown software (developed by others)". This scenario and its questions will be introduced to the interviewees as follows.

Scenario: "*You are asked by a colleague to test his software, which was developed to solve configuration problems, e.g., to set up a new car or a new computer.*"

Question 1: *"What is your strategy of testing to solve this problem? Which aspects do you have to bear in mind?"*

Question 2: *"Which cognitive skills are required for such a software exploration?"*

Question 2.1: *"Which informatics views are important for this task?"*

Question 2.2: *"Which complexity would you assign to this task?"*

Question 3: *"Are there any attitudes or social communicative and cooperative skills which are necessary to accomplish this?"*

Question 4: *"Which differences of competence levels would you expect between novices and experts?"*

Question 5: *"Could you imagine a potential pupil's procedure to solve this problem?"*

Question 6: *"Which obstacles would pupils have to cope with?"*

This scenario was interpreted through qualitative content analysis. Out of 26 interviews, eight experts were asked about such a scenario. The first results of the qualitative content analysis have to be structured according to the dimensions of the competence model. Relations between the competence components and meaning units in the interview have to be found and described (matching).

For this we use the following expressions: Answer plus number of competence component followed by the original statement of the expert (if necessary shortened). If the expert discovered a competence component, which is underestimated, this leads us to an additional answer. If the experts delivered a recommendation how to foster this needed competence component, then we add a more sophisticated description of the situation.

Firstly, K1.2 has to be proved. Therefore, a key question of the analysis process is how the experts support the assumption that testing of unknown software delivers an approach to informatics systems comprehension. The following three answers are examples of this proof of our assumptions:

Answer K1.2 (system comprehension): *"Then you need to understand fundamental mechanisms or relations or concepts, correctness of software, termination, knowledge about software ergonomics"*.

Answer K1.2 (system comprehension): *"I need a kind of model-view on the informatics system to explain the system's reactions that could be surprising. That means I need a model of processes behind the GUI"*.

Answer K1.2 (system comprehension): *"I will use my increasing system comprehension to plan the input-output relations."* The experts recommend for learners an unexpected exploration with non-systematical testing, which will fail for sure, followed by the successful systematic strategies of testing. But this should not be misunderstood as a guide line for school lessons.

The more experienced the experts were in the field of school informatics, the easier we could match their meaning units with the components of the theoretically founded competence model. This could be a hint that the competence model is not close enough related to the practice of software development. To remove doubts we trust on the evaluation of the next version of the competence model through the method of expert rating. Until then, we take this as an indicator that the rough structure of the theoretically founded competence model is appropriate.

To illustrate this, we give one example to each competence component beginning with the competence dimension K2 *Informatics views*:

Answer K2.1.1 (expectations of systems‘ behavior): *"You are not able to cope with a certain input mask if you don't know which input is expected."*

Answer K2.1.3 (usability): *"All parts of a Graphical User Interface have to be tested."*

Answer K2.1.4 (functional view): *"When the functionality and reliability of the informatics system was systematically tested, then we evaluate the other aspects of the quality of the software." (*new competence component; see Section IV/A*)*

Answer K2.2.8 (computational thinking): *"You have to learn which programming style is most appropriate for the given class of tasks. An important obstacle for this selection is the boundary of one and only one well-known programming style."*

The experts mention the handicap of the first and only successful problem solving strategy, e.g. a specific programming style. This phenomenon leads to failure, if one is matching a problem to an inappropriate problem solving strategy. A solution is a broad range of informatics strategies. The first successful informatics paradigm learned by a developer (student) is mostly applied even if it is not the best fitting solution.

Answer K4.1 (perception & anticipation of informatics systems): *"For the task of systematic testing perseverance and accuracy are indispensable for success."*

In turn, through the success you can improve your ability in accuracy and perseverance.

Answer K4.1.2 (expectations for informatics literacy & professional practice): *"A software engineer is responsible for the safety of humans and has to avoid any danger to life and limb."*

Answer K4.1.2 (expectations for informatics literacy & professional practice): *"Sensitization of pupils with respect to quality of software and responsibility."*

Answer K4.2 (social-communicative skills): *"One has to communicate with customers."*

Answer K4.2 (social-communicative skills): *"There is a serious contradiction between the competence of problem solving and the social-communicative competencies."*

It is necessary to supervise the development of social-communicative competencies, since they are not fostered as a side-effect of informatics problem solving. The task of systematic testing gives the opportunity to gain non-cognitive competencies on a higher level when the learner presents his results to other learners e.g. the explanation of use cases, the presentation of test results including the visualization of large data collections.

Answer K4.2.2 (empathy: change of perspectives & roles): *"When we test software of others, we have to learn to criticize in a fair and sensitive way."*

To foster empathy, systematic testing delivers the opportunity of mutual peer reviewing, i.e. each person has to give constructive criticism, handle criticism of others and not to insult others in a careless way while criticizing.

Answer K4.3 (motivational and volitional skills): *"This process leads to deep satisfaction with your own work and after a long period to a positive attitude towards high quality of software."*

From K1.2 to K4.3, the content analysis has shown 14 especially illuminating results in the form of support with refinements of the theoretically derived competence model. This leads us to the conclusion that the decision for this research method was very successful. The set of data allows a new version of the competence model influenced by the empirical studies (see Section IV / A).

C. Informatics Modeling

A typical scenario for K1.3 *System Development* in the expert interviews is the development of a software project or to pass a particular workflow within the software development process. In the following one exemplary scenario "Merchandise Management System" will be introduced.

Scenario "Merchandise Management System":

"You are asked to develop a software based merchandise management system for a small school kiosk.

Question 1: *"What is your course of action to solve this task? Which software engineering workflows do you have to pass?"*

Question 2*: "Which graphical models would you apply?"*

Question 2.1: *"Which informatics views are important for this task?"*

Question 2.2: *"Which complexity would you assign to this task?"*

Question 3*: "Which cognitive skills are required to develop such a software system?"*

Question 4: *"Could you imagine a potential pupil's procedure to solve this problem?"*

Question 5: *"Which attitudes, social communicative skills and motivational aspects are necessary to solve this problem?"*

In this connection, meaning units have to be derived from the interviewees' answers to *Question 1-5*. Furthermore potential relations between meaning units and components of the theoretically derived competency model have to be investigated.

Many interviewees stressed that K1.3 *System development* is an important ICT related competency and learners have to pass the workflows of professional software engineering processes.

Answer K1.3 (system development): *"We have to run through the workflows of the waterfall model."*

Answer K1.3 (system development) *"We have to pass the workflows of professional software development processes."*

The following interviewees' utterances accentuate specific software development workflows (K1.3.1 – 1.3.5) and competencies which could be allocated to them.

The K1.3.2 *Requirements* was mentioned five times. In this interrelation it was declared that learners have to be able to analyze use cases and to specify functional requirements.

Answer 1.3.2 (requirements): *"Analyze use cases to gain information about the way the system is used."*

Answer 1.3.2 (requirements): *"Specify functional requirements."*

The K1.3.3 *Analysis & Design* was mentioned by a large number of interviewees. It was stated that K1.3.3 *Analysis & Design* are processes which obey many iterations. In order to gain additional information to refine the theoretically based competency model it was expedient to subdivide these utterances to *Analysis* and *Design*. Nevertheless these workflows are strongly interwoven and will be mostly passed within several iterations [7, p. 2].

Answer K1.3.3 (analysis & design): *"Analysis Workflow has to be passed."*

Answer K1.3.3 (analysis & design): *"Object-oriented-Analysis has to be run through."*

Answer K1.3.3 (analysis & design): *"Within Analysis Workflow, learners have to envision the problem/task".*

Concerning the *Design* the interviewees mentioned that learners have to choose appropriate concepts and to develop their own conception to design an informatics system.

Answer K1.3.3 (analysis & design): *"Learners have to get familiar with several design-techniques."*

Answer K1.3.3 (analysis & design): *"Learners have to be enabled to choose an appropriate concept to design an informatics system."*

Answer K1.3.3 (analysis & design): *"They have to be able to derive potential program modules and tasks."*

Answer K1.3.3 (analysis & design): *"After all learners must get to know how to develop an own conception for designing the software."*

Irrespective of a potential distinction between *Analysis* and *Design* the interviewees listed several UML modeling techniques. This shows that learners have to be able to choose appropriate modeling techniques with respect to the actual software iteration.

Answer K1.3.3 (analysis & design): *"Learners have to apply UML-diagrams"*

Answer K1.3.3 (analysis & design): *"Develop class diagrams."*

Answer K1.3.3 (analysis & design): *"Identify potential classes."*

Answer K1.3.3 (analysis & design): *"Identify and allocate constituent parts of a class diagram, i.e. attributes, methods, associations and inheritance."*

Answer K1.3.3 (analysis & design): *"Applying state charts."*

Answer K1.3.3 (analysis & design): *"Applying deployment diagrams."*

The K1.3.4 *Implementation* was mentioned four times. In this context it was stressed that learners should be enabled to understand algorithms and to become familiar to an (Object-oriented-) programming language

Answer K1.3.4 (implementation): *"Understanding algorithms (recursive algorithms in particular)."*

Answer K1.3.4 (implementation)*: "We have to learn how to implement programs in a specific programming language and to cope with syntax errors."*

Answer K1.3.4 (implementation): *"Becoming familiar to Object-oriented-Programming."*

Answer K1.3.4 (implementation): *"Understanding the distinction between class-/object- attributes and –methods. "*

As mentioned in chapter A it is important to foster K4.2 *Social Communicative Skills* within informatics problem solving processes. Passing the *Implementation* offers the opportunity to develop software in teams.

Answer K4.2 (social-communicative skills): *"Programming in teams"*

In addition the interviewees mentioned that learners have to be able to integrate software modules (worked out by teams) into a comprehensive software system. Although the following meaning units could be allocated to the K1.3.4 *Implementation,* this might give advice to supplement the theoretically derived competence model by adding the component K1.3.6 *Deployment*.

Answer K1.3.4 (implementation): *"Synchronizing modules developed in teams."*

Answer K1.3.4 (implementation): *"Assembling modules developed in teams."*

Additionally it was stated that learners are faced with informatics system of a different grade of completion. Consequently the following meaning units might give us advice how to supplement the competency dimension K3 *Complexity of an Informatics System*.

Answer K1.3.4 (implementation): *"Learners must be able to develop software from the scratch."*

Answer K1.3.4 (implementation): *"Learners have to be enabled to get involved in an already existing informatics system and to re-engineer it."*

Answer K1.3.4 (implementation): *"They have to learn to analyze interfaces of an existing informatics system."*

The relevance of the K1.3.5 *Test* was declared by three interviewees.

Answer K1.3.5 (test): *"Testing and justifying the product's quality by comparing it to the (functional) requirements."*

Moreover the interviewees mentioned some well-established software testing procedures:

Answer K1.3.5 (test): *"Performing Blackbox-Testing."*

Answer K1.3.5 (test): *"Performing Whitebox-Testing."*

Answer K1.3.5 (test): *"Performing Regression-Testing."*

In summary this chapter illustrates several meaning units, which were derived from the interviewees' answers. These were structured with respect to the subcomponents of K1.2 *System Development*. According to this assignment of meaning units to the competence components (K1.2.1-K1.2.5), chapter IV-B will show how to refine the theoretically derived competency model, i.e. illustrating components which have to be justified, pointing out components which seem to be appropriate, showing interrelations to other competency dimensions and lining out components to supplement the model.

IV. Empirically Refined Competence Model

A. Informatics System

In this paragraph we discuss the consequences of the content analysis (see Section III / B). The competence component K1.2 *System comprehension* has to be refined with two sub components, K1.2.1 *Requirements* and K1.2.2 *Test* (see Figure 5). The following examples will illustrate this:

Answer K1.2.1 (requirements): *"You have to compare the real system's behavior with the definition of its requirements."*

K1. Basic Competencies

K1.1 System Application
K1.2 System Comprehension
  K1.2.1 Requirements
  K1.2.2 Test
K1.3 System Development
  K1.3.1 Business Modeling
  K1.3.2 Requirements
  K1.3.3 Analysis & Design
  K1.3.4 Implementation
  K1.3.5 Test
  K1.3.6 Deployment

Figure 5. New Competence Dimension K1 Basic Competencies

Answer K1.2.2 (test): Systematic testing is mentioned by all experts. This should be learned through strategies (blackbox testing, whitebox testing), manuals and tools of testing.

The competence dimension K2 seems to be very important. A criterion for the success of problem solving is the selection of the most appropriate informatics strategy related to theoretical foundations and practical tools. Denning defines views as "The five windows of computing mechanics" [10, p 17]. Therefore, a change is recommended between different solution strategies of problem solving. Several experts stress the meaning of this relation. Informatics should not be reduced to programming. Therefore, we assume that this competence dimension is incomplete if only a static sequence of K2.1 *External view* and K2.2 *Internal view* with their facets is considered and we insert a new component, K2.3 *Change of views*.

Also the competence component K2.1 *External view* needs refinement, but only with one new sub component, K2.1.4 *Functional view* (see Figure 6), including input- output relations and state diagrams.

Answer K2.1.4 (functional view): *"In my opinion the view on the whole system has to be called functional view. This is connected with the analysis of input-output relations and designing and understanding of state diagrams. "*

For the competence dimension K3 we discovered a special situation. The competence components which we used, e.g., a "count of components", are not mentioned by any expert. But new competence components like combinatorial complexity and the complexity measures, time and space, are stressed very often. This leads us to the decision to insert two components, K3.5 *Combinatorial complexity* and K3.6 *Measures of complexity: time and space* (see Figure 7). Maybe we will later skip the unsuccessful components. It is too early to finalize this decision.

Answer K3.5 (combinatorial complexity): *"It is clear that we have to cope with the combinatorial complexity of 10^{10} solutions in the process of systematical testing."*

Answer K3.6 (measures of complexity: time and space): *"To characterize the quality of the software we should use runtime performance (including efficiency) and memory requirements to evaluate an informatics system, which lead us to the complexity measures, time and space."*

Furthermore, the scalability of problem solving strategies is related to the complexity of informatics systems. We found an impressive number of experts' statements, which connect scalability with the competence dimension K2 *Informatics views*. But in an unexpected way, the experts did not mention the role of scalability in the context of *Question 2.2* on the assigned complexity. We took all pro and contra arguments into consideration and came to the conclusion that it is necessary to put scalability into the competence model as new competence component, K3.7 *Scalability*, with strong connection to the other complexity factors.

To summarize the most important results of empirical evaluation line A (Informatics systems), in the following two paragraphs we focus on a deeper discussion of K2.3 *Change of view* (see Figure 6) and K3.7 *Scalability* (see Figure 7). Both results could be seen as a bridge between the empirical evaluation lines A and B (Informatics modeling).

K2.3 Change of view: In the particular research on system comprehension (during the last four years) we developed a successful strategy of changes of views from *observable behavior* (S_A) to *internal structure* (S_B) without focus on *construction of a concrete realization* (S_C). The main advantage is the change of view from *observable behavior* (S_A) to *combination of behavior and internal structure* (S_{AB}) and then to *combination of internal structure and construction of a concrete realization* (S_{BC}) and then to *combination of behavior and construction of a concrete realization* (S_{AC}). "The learners are able to explain, why a certain internal structure has been chosen with respect to the intended behavior of the informatics system." [11, p. 7]. Further research results are two important connections, firstly between static and dynamic properties of informatics systems and secondly between exploration and development of informatics systems. On our way from a theoretically established competence model to an empirically proved one, the change of view effects also the networked thinking in different ways: networking of fundamental ideas of informatics, networking of informatics sub systems, networking of successful patterns of informatics, such as object-oriented design patterns and architectural patterns. Surprisingly this opens an approach to informatics competencies not only connected with modeling and programming but to exploration of informatics systems.

K2. Informatics views

K2.1 External view
- K2.1.1 Expectations of Systems' Behavior
- K2.1.2 Informatics Literacy & Professional Practice
- K2.1.3 Usability
- K2.1.4 Functional View

K2.2 Internal view
- K2.2.1 Layered Architectures
- K2.2.2 Net-Centric Computing
- K2.2.3 Systems of Patterns
- K2.2.4 Algorithms & Data Structures
- K2.2.5 Fundamental Ideas of Computer Science
- K2.2.6 Graphical Representations
- K2.2.7 Languages (Programming & Modeling)
- K2.2.8 Computational Thinking (imperative, functional, logical, object-oriented)

K2.3 Change of View

Figure 6. New Competence Dimension K2 Informatics views

K3.7 Scalability: Here we face the problem that most research results target on informatics modeling. We will refer to selected examples: In Informatics complexity of a problem resp. task plays an important role. Depending on the size of input n, how many resources, represented by the function f(n) are necessary to process a program on a machine. Resources may be the necessary time and space, the number accesses to the data bases etc. Some standard algorithms deliver good results for a small input size, but for a large input size they deliver bad results or no solution in a given time boundary. Therefore, the criterion scalability can be used to decide, which solution (system, algorithm, process) should be applied to different problem sets.

K3. Complexity

K3.1 Number of Components of Informatics Systems
K3.2 Level of Net-Centric Computing
K3.3 Stand-alone Systems vs. Distributed Systems
K3.4 Level of Human-Computer Interaction
K3.5 Combinatorial Complexity
K3.6 Measures of Complexity: Time & Space
K3.7 Scalability

Figure 7. New Competence Dimension K2 Informatics views

There are nearly no publications for the influence of scalability of system comprehension. One example would be to find an efficient search strategy in relation to the expected search space. This means, you should not use the same strategy for searching key words in a finite text and for application of a web based search engine assuming a huge amount of candidates in the solution set. This leads us to heuristic solution strategies. Furthermore, scalability is an evaluation criterion for the range of application of a given informatics systems or tool.

The application of the empirical method Critical Incident Technique and content analysis established seven new competence components with respect to a scenario on system comprehension:

- K1.2.1 *Requirements,*
- K1.2.2 *Test,*
- K2.1.4 *Functional view,*
- K2.3 *Change of view,*
- K3.5 *Combinatorial complexity,*
- K3.6 *Measures of complexity: time and space,*
- K3.7 *Scalability.*

The same empirical method allows removing competence components. But to be one the safe side, we decided that we use the second empirical method, expert rating, to prove the agreement of the experts with the now more completed competence model. And after this research phase, it is easier to discover redundancies and removable components. This means, we can merge different components if necessary, in case of redundancies.

B. Informatics Modeling

The component K1.3 *System development* is an important part of the competency model, because it covers essential processes and competencies to develop an informatics system. Nevertheless the analyses of the expert interviews have shown the need to refine this component.

In this connection no interviewee stressed the K1.3.1 *Business modeling* or competencies which could be explicitly allocated to it. Hence this competency component has to be justified by taking further interviews and expert ratings into account or regarded as not be relevant for system development at least on secondary level.

K1.3.2 *Requirements* was mentioned several times and seems to be appropriate at this stage of work.

K1.3.3 *Analysis & design* was stressed by many interviewees. Nevertheless there are a lot of meaning units derived from the interviewee's utterances, which could be explicitly allocated to analysis or to design. Consequently it seems to be serviceable to split K1.3.3 *Analysis & design* into these separated workflows in order to categorize competencies more precisely. As mentioned before these workflows are interwoven and will be passed within several iterations [7, p. 2]. Irrespectively the analysis of the interviewee's utterances has shown that learners have to be fostered to choose serviceable modeling techniques and an appropriate course of action with respect to the actual iteration of the software engineering process (abbreviation: *sequencing pattern*). Fostering this kind of competency enables learners to restructure knowledge in multiple ways according to changing situational demands [12] and constitutes a precondition for situational learning. The application of different modeling techniques requires static views as well as dynamic views, e.g., class diagrams to support the static view and state diagrams for the dynamic view. To foster appropriate modeling competencies, K2.3 *Change of views* is inevitable.

Additionally, adding "Sequencing pattern*"* could be another purposeful refinement of the competency model. Furthermore, the selection of appropriate modeling techniques according to the actual stage of development of the software engineering process represents the appliance of scalable informatics problem solving strategies. Hence, K3.7 *Scalability* seems to be interwoven with other complexity factors of an informatics system and justifies the supplementation of K3 *Complexity* once more. Choosing expedient modeling techniques also comprises the appliance of several UML diagrams. This competence facet could be assigned to K1.3.3 *Analysis & Design* as well as to K2.2.6 *Graphical representations* and illustrates the linkage between K1 *Basic competencies* and K2 *Informatics views*.

As illustrated in chapter III / C K1.2.4 *Implementation* is an essential workflow within software engineering processes. The illustrated meaning units show its interrelation to other dimensions of the competency model. In this connection *understanding of algorithms* can also be assigned to K2.2.4 *Algorithms & data structures* and constitutes an important internal view on an informatics system. In addition to K1.2.4 *Implementation,* object-oriented programming can also be allocated to K2.2.7 *Languages (programming & modeling)*. These interrelations illustrate the linkage between K1 *Basic competencies* and K2 *Informatics views*. Furthermore the interviewees mentioned that learners have to be fostered to develop an informatics system from the scratch and to re-engineer an already existing informatics system, i.e. analyzing interfaces or integrating new program modules into a comprehensive system. These different approaches might illustrate the handling with informatics systems of a different grade of completion. Hence, “grade of completion” might be an appropriate competency component to describe informatics systems of varying complexity. Consequently this competency component might be useful to supplement K3 *Complexity*.

In addition to the interviewee’s utterances concerning the system’s completion many interviewees declared expressly that learners have to be enabled to synchronize and to assemble program modules (developed by teams) in order to integrate them into a comprehensive informatics system. Accordingly it seems to be expedient to supplement K1.3.2 *Requirements* to the competency model. Additionally synchronizing and assembling program modules demands K4.2 *Social-communicative skills*. In this context workgroups have to agree to common interfaces for instance. This fact shows, that K1 *Basic competencies* is also related to K4 *Non-cognitive skills*.

K1.3.5 *Test* was also mentioned by many interviewees and seems to be appropriate as a constituent part of the competency model.

The application of the empirical method Critical Incident Technique and content analysis established two new competence components with respect to a scenario on system development:

- K2.3 *Change of view,*
- K3.7 *Scalability.*

This chapter focuses the empirical refinements of the theoretically based competency component K1.3 *System development*. In this context almost any of the subcomponents (K1.3.1-K1.3.5) seem to be appropriate. Furthermore there are several interrelations between the competency dimensions (K1 to K2, K3, K4). In addition, it has shown to be serviceable to add new components to the theoretical model. Particularly adding “Sequencing pattern” indicates that informatics modeling covers competencies to consciously select problem solving strategies according to the respective context the learners are faced. The supplementation of “Deployment” shows that modules worked out by working groups have to be consolidated in an expedient manner. Consequently it is inevitable to foster K4.2 *Social-communicative skills* explicitly and they should not be treated as negligibility.

V. Conclusions

As highlights of this article we summarize two research results, which will influence our further work in a specific way. These are *Scalability* and *Change of view*.

Scalability was found through the different research perspectives, informatics systems and informatics modeling. One important conclusion in Section IV / A was the criterion scalability can be used to decide, which solution should be applied to different problem sets. Another important conclusion in Section IV / B was that the context specific selection of modeling techniques represents the application of scalable informatics problem solving strategies. For the reader it is obvious that the person who is faced with an informatics system plays different roles, firstly as an explorer of informatics systems, secondly as a developer of such systems. It would be possible to describe both phenomena with different expressions to distinguish these aspects of scalability. But we decided to combine the two conclusions in one more abstract competence component K3.7 *Scalability*, because both aspects constitute the appropriate problem solving strategy.

In the same way we found change of view through the different research perspectives, informatics systems and informatics modeling. The research perspective on informatics systems delivers the next conclusion; the change of view affects the networked thinking in different ways. The analogue conclusion from the perspective of informatics modeling leads to K2.3 *Change of views*, which is inevitable to consciously use different modeling techniques.

This article presented first exemplary results of an empirical approach to determine competencies with reference to the domains *Informatics System Comprehension* and *Informatics Modeling*. The described results suggest that refinements and supplements to the theoretically derived competence model can be accomplished. On the basis of 17 from a total of 30 interview transcripts, it has been shown how the interviews were conducted and analyzed. Furthermore, it has been demonstrated how the results were applied to prove the theoretically derived competence model and to refine and supplement the model.

The described empirical procedure to complement the theoretical model is nevertheless restricted: One methodological restriction includes that the relevant competence requirements cannot be actuated comprehensively by the used scenarios. So it is important that the scenarios contain at least typical and representative tasks and problems to solve. This was evaluated by the represenativeness ratings of the experts. Furthermore, the actions described by the informatics experts might not necessarily mirror their actual behavior in those scenarios because they could describe idealized actions to solve the problems in the scenarios. On this issue, the different orientations of expertise of the interviewees serve as a corrective to some extent. The deployment of the qualitative content analysis took place adhering to comprehensible, methodical rules and principles. Nevertheless, qualitative analyses include inevitably interpretative processes which might restrict the objectivity, reliability and validity of the described analyses.

So it is necessary to prove the resulting competence model in further empirical research steps focussing on the content and criteria validity of the model. In a first step informatics experts with different backgrounds of expertise shall evaluate the relevance, difficulty, representativeness and differentiation of the determined competencies to prove the content validity of the model. The analysis of the criteria validity of the model is focussed on the following question: Do the determined competencies describe the requirements of successful acting in a sufficient manner? In order to answer this question, instruments to measure the different facets of the competence model and the criteria behavior have to be developed. Based on these measurements, then the correlations between the levels of competence on the one hand and the successful problem solving behavior as criteria on the other hand can be interpreted as criteria validity indicators of the competence model.

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Introducing multidisciplinary thinking in Computer Engineering: A new way of teaching database systems

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Abstract—**This paper describes an experiment conducted in Brazil in teaching an undergraduate database course to Computer Engineering and Computer Science students at the University of Campinas (UNICAMP). The experiment has introduced advanced (graduate-level) material in this introductory course, showing students how to integrate course material into several other subjects. The ultimate goal is to engage students in a richer learning environment, enhance motivation, broadening their horizons, and showing them how to solve problems in other fields by looking at a problem from distinct angles.**

This work was conducted within a binational research project involving UNICAMP/Brazil and Jacobs University/Germany.

Keywords- computer science education; multi-disciplinary teaching; non-standard databases; raster databases

I. Introduction and Motivation

Computer Engineering (CE) and Computer Science (CS) courses are seeing a progressive drop in student enrollment in several countries – see, e.g., the annual CRA report [1]. Given the pressing need for qualified manpower in this area, universities all over the world are updating their curricula, or introducing new course modalities, to attract a wider spectrum of candidates. Furthermore, traditional subjects are being restructured to show students how to apply what they learn to new domains.

The University of Campinas (UNICAMP, Brazil) is not an exception to this activity. It is one of the country's foremost universities. Undergraduate computer science courses have been introduced in 1969, making them oldest in the country. The UNICAMP computing courses are consistently rated among the country's top five courses (out of roughly 2,000 computing courses).

Besides being responsible for two undergraduate curriculae (in Computer Science and one modality of Computer Engineering) and the graduate program in Computer Science, the Institute of Computing is also responsible for the basic education in computing for the entire university. This increases its responsibility in keeping its courses up-to-date and tailoring them to specific needs (e.g., for Arts or Biology students). Hence, the contents of computing courses go through frequent updates as part of the university's policy of training high-level professionals.

This paper describes results of applying one such modification, in an experiment which was conducted during the first semester of 2009. The experiment concerns teaching database management systems to second year CS and CE majors.

The main goal of this experiment was to introduce a new way of looking at databases, showing students how they could combine what they were learning during this course with what they had seen in other subjects, so that they could solve problems in other sciences. As an experimental platform the rasdaman system [2][3][4] was adopted. This is an open source database system geared towards the management of multi-dimensional raster data, i.e., arrays in a programming sense. Rasdaman allows students to query different kinds of scientific data stored and managed by a database management system; in our case, this is PostgreSQL [5]. With its raster query language, rasql, rasdaman smoothly extends the retrieval capabilities of SQL to multi-dimensional sensor, image, and statistics data as they appear in manifold variations in the earth and life sciences and beyond, such as astronomy.

The paper discusses our findings on extending classical database teaching with a non-standard, but SQL-like retrieval language which allows performing visual query experiments in domains appealing to "techies". Discussion is based on tests applied during the course and a questionnaire filled by the students. These findings point at the interest of motivating basic computing courses with multidisciplinary material from other disciplines. They also show that it is possible to adapt graduate level subjects to an undergraduate course. This not only helps those who are interested in pursuing graduate work, but also shows students the need for first learning the basics, so that afterwards they can understand advanced topics.

The remainder of this paper is organized as follows. Section II briefly presents the contents of a basic database course, and comments on how it is being taught at UNICAMP. Section III discusses advanced material used in our experiment, usually considered at graduate level. Section IV presents rasdaman, the retrieval tool used here. Section V follows on this by comment-

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ing on the exercises applied, and analyzing the results. Section VI covers some related work. Section VII concludes the paper.

II. Teaching Database Systems to undergraduate CS students

A. *Basic course material*

Traditionally, basic database management courses cover two complementary aspects: modeling and design, centered on creating a database from a given set of user requirements; and internals of database systems, covering issues such as query optimization, transaction processing and storage structures. These two aspects are often treated in separate courses, the first emphasizing user-related problems, and the second systems implementation issues.

These subjects are usually considered as part of the core of Computing curricula – e.g., [6] – being taught within not only Computer Science and Computer Engineering programs, but also in MIS-related programs [7]. However, in spite of the immediate application of what they learn in this course, students are seldom able to generalize the concepts.

This is, of course, not a problem particular to database teaching, but rather concerns the way courses are often taught in the credit-based system. One way to approach this problem is to introduce projects to be solved by teams [8]. This approach, sometimes called "Project-based learning", is common to many engineering and technological courses, helping students to learn to work together, an essential skill for all professionals. In particular, in database courses, students are given a problem and have to solve it by designing and constructing a database, and subsequently develop an information system on top of this database, accessible by "end-users".

This requires several basic computing skills, such as requirement analysis, programming and designing data structures. For this reason, database courses should never be offered in the first year of study of CS or CE majors.

B. *Teaching databases – connecting with other courses*

The approach of teaching databases separately from the users' and from the system's point of view gives lecturers and students more time for each subject. On the other hand, students find it difficult to connect the two views. Thus, at UNICAMP, we have designed a basic course that combines both aspects. Students may afterwards take additional credits on advanced topics.

The first author has been teaching database-related topics for over 24 years at UNICAMP, striving to connect course content with other courses [8]. This approach is based on showing students that they can use material covered in databases as a means to partially reviewing other courses they have taken, as well as a preview of other courses.

Course material and exercises are divided into user-related and systems-related. Each topic is introduced with examples and motivation from other topics, always reminding students that subjects cannot be considered in isolation. Table 1 summarizes this approach. Column 1 enumerates a few basic course subjects, and Column 2 indicates courses in which related subjects are taught. The first three lines are mostly user-related concerns, and the SQL language is used as an entry point to systems issues, which are covered in the last four columns.

C. *Barriers to overcome – bringing the curriculum up to date*

Like in any other CS subject, there is a need to combine two sometimes conflicting goals – to cover the necessary basic material, and introduce advances and state of the art questions to prepare students for their professional life.

Our experiment, discussed from now on, combined these goals. As will be seen, we introduced advanced graduate material in the introductory database course – namely, non-standard queries and applications. To further motivate students and enhance learning, we used a raster query engine so that they had a practical, hands-on experience of visually interesting material.

III. New paradigms – non-standard queries and applications

Databases are omnipresent in industry, science, and government, hence there is a plethora of practical examples just waiting to be exploited for teaching. Still, in today's classrooms the prevailing scenarios center around business applications or academic administration ("students – teachers – courses"). However, our observation is that at least Computer Science and Engineering students typically have a high technical/scientific affinity and feel much less enthusiastic about administrative and business scenarios. Hence, scientific use cases bear a significant motivation potential for this audience.

TABLE I. Relating database and other subjects

Course Subject	Other courses
Database modeling and design Requirement elicitation	Software engineering Interface design
Map conceptual to logical levels (e.g, ER to relational) Normalization	Algorithm design Logics
Formal query languages SQL basics	Compilers Logics Interface design
Query optimization	Compilers Operating systems Software engineering
Transaction management	Operating systems Algorithm design Distributed systems
Concurrency control Recovery mechanisms	Operating systems Distributed systems Algorithm analysis
I/O and data structures	Algorithm analysis Computer networks

An additional shortcoming is the lack of appealing visual effects – generally, a database course is perceived much less exciting than, e.g., computer graphics and visualization. Typically, visualization in databases is only addressed when it comes to a condensed presentation of query results to support human grasping of properties embedded in large data sets [10]. Taking advantage of a truly visual semantics normally is not addressed; even multimedia databases aim at extracting semantic information from images to later on query only alphanumeric data, but not the images themselves.

Aside from motivational reasons, exposing students to non-classical data and query models bears a value because it widens the horizon and avoids hardwiring the equation

“databases ≡ SQL”

in the students’ brains. Addressing XML databases is one possible counter measure, but these are not necessarily exciting in terms of visual presentation and use case scenarios either.

Our approach attempts to leverage the benefits of truly visual information for database education. In this approach, it does not matter whether students later on in their professional lives deal with such kind of data and query models – the driving forces in this experiment are (i) student motivation through visual experiences with scientific semantics and (ii) extending the students’ horizon beyond “classical” SQL.

To this end, we chose scientific sensor, image, and statistics data as our target. Most often, when sampled or generated from simulations, these come as raster data of some specific dimension and cell (“pixel”, “voxel”) type. In the earth sciences, for example, we find 1-D sensor time series, 2-D satellite images, 3-D x/y/t image time series and x/y/z exploration data, as well as 4-D x/y/z/t climate and ocean simulation data. Queries on them can rely on use case scenarios which are practically motivated, related to hi-tech appealing to students, and lead to query results that can immediately be verified visually. Actually, this work to some extent is a spin-off from ongoing standardization activities by the German partners where, for the Open GeoSpatial Consortium (OGC) Web Coverage Processing Service (WCPS) standard developed by Jacobs University; a demonstration site with a hands-on sandbox has been established at [10].

At the same time, the information category of raster data is so generic that use cases can be found in many domains beyond geographic applications. Other areas include topics as diverse as diverse human brain imaging, gene expression analysis, radio astronomy and cosmological simulations, and even psychology (where our current research addresses quantitative emotion analysis).

IV. RASQL OVERVIEW

The conceptual model of rasdaman centers around the notion of an n-D array (in the programming language sense) which can be of any dimension, spatial extent, and array cell type. Arrays are functions f:$D \rightarrow V$ from some domain D, which is a subset of d-dimensional Euclidean space $\mathbf{Z}^d$, into some value set V. A rasdaman database can be conceived as a set of tables where each table contains a single array-valued attribute, augmented with a system-generated object identifier suitable for foreign key references (Figure 1).

The rasdaman query language, rasql, offers an algebra-based query language [4] which extends standard SQL92 with declarative MDD operators suitable for a wide range of signal processing, imaging, and statistical operations. Server-based query evaluation relies on extensive logical and physical optimisation and a streamlined array storage manager [3]. Fro a teaching perspective, therefore, all conventional (i.e.: known from SQL) query language principles can be found and discussed.

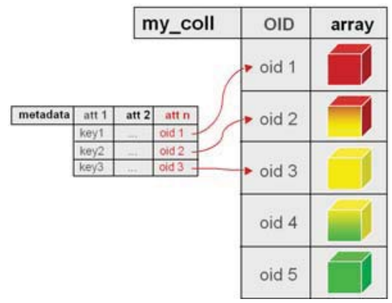

Figure 1. The rasdaman conceptual array model

A. *Raster Retrieval*

We introduce rasql only briefly, with a walk-through guided by didactics rather than by completeness; see [1] for a more comprehensive and formal treatment.

Like SQL, a query returns a set of items (in this case: either arrays or, for summarization queries, scalars). *Subsetting* of arrays includes *trimming* (rectangular cutouts) and *slicing* (extraction of lower-dimensional sub-arrays). The following query retrieves a 2000x3000 cutout from every Landsat satellite image in collection `LandsatImages`:

```
SELECT ls[ 1001:3000, 1001:4000 ]
FROM   LandsatImages AS ls
```

This works for any number of dimensions, and also allows wildcards to refer to the array boundaries. Let us assume that `ClimateCubes` contains 4-D cubes with time being the first dimension. The following query, then, extracts a 3-D spatial volume at time step 1020:

```
SELECT cc[ 1020, *:*, *:*, *:* ]
FROM   ClimateCubes AS cc
```

For each operation available on the raster cell type, a corresponding so-called *induced operation* is provided which applies the base operation to all cells of an array simultaneously. Both unary operations (e.g., record access, cast operations, or constant multiplication for contrast enhancement) and binary operations (e.g., masking an image) can be induced. An example is "*Band 3 of all Landsat images, with intensity reduced by a factor of 2*":

```
SELECT (char) (ls.band3 / 2)
FROM   LandsatImages AS ls
```

Not only arithmetic, but also boolean operators can be induced. Figure 2 (left) shows the three visible bands of a satellite view on the South Spanish coast. The query below masks out all non-green pixels from this image; the boolean result of the parenthesis expression is interpreted as 0 or 1, resp., so that a *false* value maps to black and a *true* value retains the original color value:

```
SELECT (    ls.green > 130
        AND ls.red   < 110
        AND ls.blue  < 140
       ) * ls
FROM   LandsatImages AS ls
```

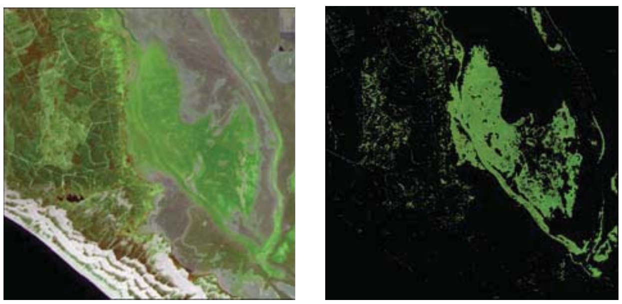

Figure 2. Landsat scene (left) and green detection (right)

In general, array expressions can be used in the `SELECT` part of a query and, if the outermost expression result type is boolean, also in the `WHERE` part. Therefore, we need a means to ”collapse” raster-valued expressions, such as induced comparisons, into scalar boolean values. This is accomplished through so-called *condensers* which summarize over the array values, representing the counterpart to SQL aggregation. Based on a higher-order generalized construct the usual aggregates are defined, such as *count*, *average*, *min*, *max*, *all*, and existence quantifiers. For example, the following query retrieves the “*percentage of green area per region in Landsat scenes*”.

```
SELECT   count_cells( ls.green > 127 and r )
       / count_cells( ls and r )
FROM   LandsatImages AS ls, Regions as r
```

The `MARRAY` operator constructs a new array with some given extent and a contents determined by a scalar expression used to assign a value into each raster cell position. To this end, it defines locally scoped cell coordinate iteration variables. For example, a 256x256 checker-board array can be defined as

```
MARRAY x IN [0:255], y IN [0:255]
VALUES mod( x + y, 2 )
```

In practice, `MARRAY` frequently appears in conjunction with condensers. The following example illustrates this, deriving a histogram from 16-bit brain scans of unknown dimension:

```
SELECT MARRAY n IN [0:16535]
       VALUES count_cells(b) = n
FROM   BrainScans AS b
```

Advanced applications of this pattern include filter kernels, general convolutions, up to the Fast Fourier Transform. Interesting parallels also can be found to the relational GROUP BY / HAVING clause. A theoretical analysis of the expressiveness and complexity of array indexing expressions is given in [4].

In contrast to alphanumeric query results which can be readily printed, raster results need to be encoded for display. The following query delivers spectral band 3 from all Landsat images, encoded in JPEG:

```
SELECT jpeg( ls.band3 )
FROM   LandsatImages AS ls
```

B. *Storage and Processing*

The storage model adopted by rasdaman is based on multidimensional *tiling*, i.e., a user-definable decomposition into rectangular sub-arrays of suitable size (Figure 3). Tiles are stored as BLOBs (binary large objects, i.e.: linearized byte arrays) in a standard relational database system, such as PostgreSQL.

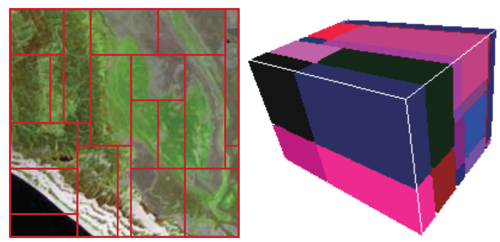

Figure 3. Sample 2-D and 3-D tiling

Query processing relies on *tile streaming*: operator tree nodes read data tile by tile, process them, and pass on result tiles to the next higher node. This way, arrays of unlimited size can be processed without limitations imposed by server main memory. See [3] for further details.

C. *Front-End Tools*

For the purpose of our experiment, two tools have been provided. *Rview* is a graphical-interactive tool which allows submitting queries typed into a text window, retrieving result sets, and visualizing them in various ways, including 1-D charts, 2-D tables and images, and 3-D animations. The *rasql* tool allows submitting queries via command line and store results in files or, alternatively, output them directly to the console. Especially the latter feature, in combination with an ASCII output format, allows inspecting particular data values in detail and with Unix tools well known to the students at this stage.

V. EXPERIMENT EVALUATION

In order to describe the experiment, we first situate the database course in the CS and CE curriculum and next discuss the students’ academic and work profile.

The experiment of reorganizing the database course was conducted during 4 months (from March to June 2009) in a 90-hour undergraduate introductory database course. This course is organized in 6 hours per week, of which 2 are for hands-on exercises and the other 4 dedicated to theoretical classes.

In the first semester of 2009, this course was offered to a class of 65 students in the evening. The Institute of Computing offers both day and night computing courses. The night course offers a bachelors degree in Computer Science; the day course offers a degree in Computer Engineering. The contents of most computing related courses are the same, though CE has many more credits to cover engineering requirements. In particular, the database course is offered on the fourth or fifth semester of both degrees, and students have already taken courses on programming, data structures and operating systems.

Academically, day and night students are very similar – university entrance examinations are very competitive at UNICAMP, and are conducted on a country-wide basis. Every year, acceptance rate for CE and CS is between 20:1 and 25:1 (though in the beginning of the nineties the competition was as high as 35:1). Hence, only very good students are accepted in our courses.

On the other hand, the profile of students who take night classes is very different from those in day classes. First, most students are employed, and even though in the same age range as day students (e.g., between 18 and 23) they are usually more mature and take their course work more serious. Second, they have a more practical mindset, in the sense that they are always looking for ways to apply what they are learning to solve problems they are facing in their jobs. Finally, since courses take place from 7 to 11 PM every day, plus Saturday mornings, lecturers have to work hard to keep students interested. In this sense, rasdaman exercises were a big success – the students had never experimented with such a system, or worked with such examples (at work or school) and were noticeably motivated by the new kind of exercises. This was also indicated in their answers to the questionnaire – all said they would be willing to participate in similar rasdaman experiments in the future (last question of the questionnaire).

The course material was reorganized in three stages. Eight percent of the 90 hours allotted to the course were occupied exclusively by introducing rasdaman – roughly, 3 hours of theoretical issues and 4 hours of hands-on exercises. Additional hours of graduate level material were also taught, to provide the theoretical basis on non-standard database management issues and multi-dimensional data. From the start, students were told that the course would be "different", i.e., that besides covering the required material they would use a new kind of database system, and that they would be experimenting with novel applications.

First, students were introduced to the basics of database management systems. This was accompanied by motivation on how database systems are needed (and profit from) other subjects, such as VLSI design, climate modeling and astronomy. Here, the notion of raster data structures was also introduced, preparing the ground for the use of rasdaman.

This first half of the course comprised the subjects involving user-related external issues (i.e., database design and querying formalism, see Section II). Each subject was accompanied by practical exercises. Students also had to develop a set of small database applications (in PostgreSQL [5]), to familiarize themselves with database creation and query specification.

Next, students were presented with the internals of database management systems, especially query optimization and transaction management. At the same time, additional material was presented, covering rasdaman basics [3]. First, there was an introduction to the rasql language, showing how it supported queries to raster data. Basic database material seen in the first half of the course was revisited during this stage, showing how it could be used to solve problems in scientific data handling - e.g., in environmental control, image analysis in health studies and in biodiversity. This was accompanied by hands-on exercises on examples of rasql.

Finally, they were introduced to rasdaman architecture, which was compared with the architecture of standard DBMS. For instance, they were shown how query processing in rasdaman was just an instance of DBMS query processing, with adaptations to support vectors and matrices. Further experimentation on rasql was introduced at this stage.

Each exercise was followed by challenges, e.g., asking the students to pose variations of an initial problem. Exercises grew in complexity, starting with simple one-dimensional data handling to processing movies and data cubes (e.g., of geological data, or temperature time series). The tasks to which the students were exposed included the following challenges:

Challenge 1: What is the difference in terms of the result structure of these two queries?

```
SELECT b                  SELECT avg_cells(b)>10
FROM   BrainScans AS b    FROM   BrainScans AS b
WHERE  avg_cells(b)>10
```

The first query obviously would return a subset of the stored images while the second one would return one scalar boolean value per image. Result visualization made the students aware of the data structures generated during query evaluation and allowed them to visually compare the results.

Challenge 2: Generate an array as shown in Figure 4.

A possible answer is this query:

```
SELECT MARRAY x IN [0:10],
              y IN [0:10]
       VALUES (y > x)
FROM   rgb
```

This shows how coordinate positions can influence a cell's value through index arithmetics and, at the same time, highlights one of SQL's issues: no result can be delivered without indicating a table, even if this table is not used for the result.

Challenge 3: Generate the result shown in Figure 5 (right) for a given circle center (x0/y0) and radius (r).

	0	1	2	3	4	5	6	7	8	9	10
0	0	0	0	0	0	0	0	0	0	0	0
1	1	0	0	0	0	0	0	0	0	0	0
2	1	1	0	0	0	0	0	0	0	0	0
3	1	1	1	0	0	0	0	0	0	0	0
4	1	1	1	1	0	0	0	0	0	0	0
5	1	1	1	1	1	0	0	0	0	0	0
6	1	1	1	1	1	1	0	0	0	0	0
7	1	1	1	1	1	1	1	0	0	0	0
8	1	1	1	1	1	1	1	1	0	0	0
9	1	1	1	1	1	1	1	1	1	0	0
10	1	1	1	1	1	1	1	1	1	1	0

Figure 4. Task input for generating given data patterns

Figure 5. Extracting geometrically defined areas

The expected answer is a query like this one:

```
SELECT rgb *
       MARRAY x IN [0:199],
              y IN [0:199]
       VALUES (sq(x-x0) + sq(y-y0) < sq(r))
FROM   rgb
```

During this part of the classes, several students suggested the use of rasdaman to help teach calculus and linear algebra. They proposed examples of its use in such classes, and were excited at being able to connect the contents of a database course with the more theoretical subjects they had seen the previous year.

Handling images and movies was also another source of interest. Several of them were familiar with movie editing tools, but never from a purely mathematical point of view. Though all were aware of images as 2D and movies as 3D objects, they had never practiced slicing and dicing frames – especially using a database framework. Details on course material for the rasdaman classes appear in [13].

As we all know, hands-on exercises are the most efficient form of learning. However, students mostly see such exercises as a means to practice course material, and are seldom able to see how courses can interconnect. Here, they not only experienced working with a database. To solve the exercises, they had to recall (and thus make the mental links to) notions in linear algebra, boolean algebra, calculus and physics. For instance, in the questionnaires one student commented that for the first time he understood how equations work in practice.

The appendix shows the questionnaire filled by the students. In the original questionnaire, all questions were accompanied by answer options (e.g. "YES, explain why"; "NO, explain why not"). These options have been omitted for the sake of brevity, and only the questions have been included.

All students said they had never seen any database system that was similar to rasdaman – including those that said they had already worked with maps, but never with multidimensional raster data management. They all said the classes were interesting, and 90% would be willing to participate in further exercises. Most said that this system could be used in other courses (examples cited included mathematics, physics, operating systems and image processing). Half of the respondents said that there should have been more of the internals covered, so they could understand "how it works".

Twenty percent of the respondents said that they thought this kind of topic should be left to advanced undergraduate courses. Interestingly enough, those who gave this opinion work as database administrators or database programmers. Thus, they looked at the course from an immediate, vocational view (which is not the main focus in UNICAMP teaching approach).

One of the course's exams also contained one question on rasdaman, asking students to describe its main characteristics and functionality. The idea was not to check whether they knew rasql syntax, but to see how they would describe the system's capabilities. Twenty percent of the students did not answer this question (a few said they had not gone to the hands-on classes). The majority correctly identified the possibility of managing raster data, with examples of what they had seen in class.

VI. RELATED WORK

This section discusses related work in teaching databases and in introducing multidisciplinarity in CS courses.

Curricular issues in computing are now treated in terms of Grand Challenges by joint ACM and IEEE education committees [14]. One of the problems is that computers and computing basics are used in all domains, and there is a need for approaching subjects at distinct levels of complexity and for all kinds of majors – from the Arts and Humanities to Engineering. One consequence of this ubiquity is that CS and CE majors now have to think in a multidisciplinary context, applying what they learn to problems in other domains. However, this requires major curricular modifications, and (re)training lecturers to teach traditional subjects establishing links with other areas.

Multidisciplinarity is being moreover seen as a solution to another problem afflicting CS and CE degree-offering programs – the decrease in student enrollment and the number of drop-outs. This second problem has given rise to the appearance of many new degrees – e.g., [15] – and to new ways of teaching computing, often emphasizing human and social aspects [16]. Multidisciplinary teaching has been established as one of the priorities of the Brazilian Computer Society as a prerequisite to training the future generations of professionals and researchers [17]. Our experiment in teaching databases has gone in this direction, showing students how to deal with problems arising in other domains by working with database concepts.

Within this multidisciplinary context, data management is seen as a primary concern, for professionals and researchers alike. If Computer Science is considered to be the "third pillar" of scientific research (along with the pillars of theory and experimentation), then data concerns the fourth one [18]. As exemplified in Section II, subjects covered in database courses can be linked to several other computing subjects. Moreover, as practiced in our course experiments, database-related issues can be used to support the solution of problems in other disciplines. For this reason, database courses present a very good starting point for implementing curriculum modifications.

Given this role of databases in curricular content, there have been many proposals for teaching this subject (e.g., [7], [8], [19], [20], [21], [22]). However, as mentioned by [19], educators face a dilemma when it comes to database education.

Indeed, database concepts have continued to expand, with the creation of many specialized database systems. Moreover, advanced topics of ten years ago have now become basic topics in many situations, especially with the advent of the Web. The latter is forcing computing courses to adapt to this new environment. Database projects have migrated from stand-alone applications to distributed Web-based platforms, which has been the case in our experiment, too –in the use of both PostgreSQL and rasdaman.

The survey conducted by [7] also points out in this direction – database courses are now adapting to cover scalability, and the need to accommodate Web-based skills. Advanced topics are also proposed by [19][21][22]. While [19] introduces advanced topics in a second course, and [21] and [22] propose a suite of courses to accommodate topics, we introduced multi-dimensional data management (a graduate subject) in the first basic course. Students were motivated by this change, though those who work with database systems were more concerned with the immediate application of course content to their daily jobs, and thus did not see the usefulness of learning advanced material in a first course.

Finally, other authors stress specific points of curricular issues involving databases. Some, like [23] or [24], emphasize the need for treating data security as a concern of all that deal with data management [22], or the importance of basics such as transaction management [24] to provide students with a solid conceptual basis for subsequent studies. Others, like [25], see database courses as a way to help non-majors in collaborative learning. In his findings, a database project immerses students in the solution of real-life problems, thereby better motivating the learning experience. Like [24], we stress basic principles and mechanisms, to subsequently show how they can be instantiated in other situations. Like [25], we consider projects to be a good platform to enhance collaboration. The latter was also observed during the rasdaman exercises: since they required remembering subjects from linear algebra and mathematics, several students would get together to solve the exercises. Security, on the other hand, is just mentioned in UNICAMP's course, being covered in advanced topics. However, it could well be introduced as part of a broader problem – that of ethics, nowadays a part of CS curricula.

Finally, it must be stressed that there is no such thing as "one size fits all". While this refers to the discussion in [26] of issues in teaching an introductory CS course, we firmly believe there are domain-specific requirements that cannot be accommodated in a single course. Moreover, student background and expectations have to be taken into account. Thus, our experiment can be replicated only in similar environments – i.e., for students taking CS or CE degrees which require a solid background in mathematics, plus data structures and programming. In particular, such courses will have to take the evolution of data structures into consideration. This is the point stressed by [27], showing how data structures are evolving to consider advanced access methods and parallelism. Computing education must continue to enforce basics, while at the same time emphasizing new kinds of computational thinking.

VII. CONCLUSIONS AND ONGOING WORK

This paper discusses an experiment in teaching database management basics at the undergraduate level by combining standard course material with advanced topics. Besides working on traditional exercises with database tables, students had to practice handling and querying scientific raster data. Exercises were motivated by problems found in other disciplines, especially geography, biodiversity, and physics.

The results of this experiment, analyzed both in course exams and via a questionnaire applied after the course, indicate that it was successful in several ways. First, students' motivation in practical exercises was enhanced. Second, they became interested in browsing Web sources for additional material, connected with other (non business-oriented) uses of database systems. Finally, all students gave very high grades to the usefulness and interest of the exercises with multi-dimensional raster data.

The latter findings are particularly interesting since this was an undergraduate night course in which 90% of the students already work in IT-related jobs (e.g., as programmers or systems analysts). Since exercises relied on data from scientific domains, we did not expect that students would rate them as highly useful, considering that they do not directly relate to their jobs. However, comments on the questionnaire say that they relate usefulness to (a) having learnt new concepts, (b) having understood that database systems are not limited to tuple-oriented transactions, and (c) having discovered that a database system can be used to practice other subjects, such as computational geometry or linear algebra.

We intend to extend this experiment to other semesters to obtain a broader basis on which we can build a more solid exercise base. This will require, moreover, preparation of more concise data sets so that students can conduct several small experiments in a single class on subsets of the same data, and compare results.

Additionally, we will carry out the same experiment at the German university involved to get a broader basis for evaluating our results.

Another extension is to use the same approach in other courses. The first author is adapting some of the material used to teach an introductory CS course to Arts students, in 2010. In this case, the emphasis will be on examples for handling multimedia, and rasdaman will be used as a tool, but not a system to learn database concepts.

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APPENDIX: QUESTIONNAIRE

This appendix contains the questionnaire handed out to the students in both classes to obtain feedback on our approach.

This questionnaire on the classes you had about rasdaman is important for the planning of future offerings of the subject. It will also be used as a basis for a scientific paper. A summary of the main results will be sent to all respondents. Thank you for your collaboration.

Please answer all the questions. In doubt, answer "I have no opinion about this subject". Always answer in the space below the question. You can write as much as you want.

1. This kind of use of databases and DBMSs was new to you, or had you already seen something similar? If not new, please explain.

2. Were the classes on rasdaman useful in your training? Give an example of what you learnt towards this goal.

3. What were the highlights of the classes? And the main shortcomings?

4. Were there some topics that you think should have been covered?

5. Was the time alloted to cover the material adequate (3 classes – approximately 8 hours)? If not, how many hours would you recommend? [Why]

6. Was the number and type of classes adequate (1 theoretical class, 2 hands-on classes)? If not, what would you recommend? [Why]

7. Was the material used appropriate (PDF slides)? If not, what else should have been provided?

8. Do you think the material of these classes could also be presented in other courses? If yes, give an example.

9. Would you recommend we give these classes for the next offerings of the database course? [Why]

10. In an interval from 1 (minimum) to 5 (maximum), which grade would you assign to the rasdaman classes, considering the entire experiment (content, methodology, material)?

11. Would you like to participate in other activities using the same software?

Engineers and their practice: a case study.

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***Abstract*— There has been a growing awareness of the need for models of engineering practice in recent years and the publication of The New Production of Knowledge [1] by Gibbons led to considerable attention being focused on two distinct modes of knowledge production: Mode 1 associated with a traditional academic discipline-based approach and the more recently-emerged Mode 2, a problem-focused process more common in the entrepreneurial sphere.**

The case-study reported here originally set out to use Gibbons' models to characterize the work of a group of Portuguese engineering researchers over a 15-year period. The study employs a qualitative methodology and narrative approach to characterize practice within this group of engineers so as to look for appropriate lessons that can be applied to engineering education to better prepare future professionals.

Analysis of the information gathered during the study has caused us to question our original model of engineering practice and leads us to the conclusion that the Unifying Model recently proposed by Trevelyan [2] could represent a better fit to characterize the activities of this group and would suggest a need to gather empirical data on engineering practice.

Keywords*: *Model, engineering practice, knowledge production, case study

I. INTRODUCTION

Engineering design often tends to be addressed in engineering schools from a post-positivist perspective. This approach arguably produces professionals best prepared for the classic industrial age when processes were more stable and durable than they are today or will be tomorrow. With globalization and the development of new communication technologies the production of knowledge has naturally moved from a linear, explanations-oriented model to one which revolves around networked innovation in a solutions-oriented world and in general we can say that the practice of engineering design in industry and academia have been getting closer. The publication of The New Production of Knowledge by Gibbons et al in 1994 [1] led to considerable attention being focussed on two distinct models of knowledge production, identified by these authors as Mode 1 (associated with a traditional academic discipline-based approach) and the more recently-emerged Mode 2 (a context-driven and problem-focused process more common in the entrepreneurial sphere). The differences between these two approaches as recently characterized by Figueiredo and Cunha [3] are summarized as follows:

TABLE I. PARAMETERS ASSOCIATED WITH GIBBONS' MODES 1 AND 2 OF KNOWLEDGE PRODUCTION

	Mode 1	**Mode 2**
Context	academic, scientific	economic and social applications
Innovation	linear	problems are set and solved in the context of application
Community	disciplinary, homogeneous teams, university based	transdisciplinary; networked; heterogeneous actors
Orientation	explanation, incremental	solution focussed
Method	repeatability is important	repeatability not vital (there may be secrecy/copyright issues)
Quality assurance	peer-review is central	context dependent: may involve peer-review; customer satisfaction
Definition of success	scientific excellence	efficiency; satisfy multiple stakeholders: commercial success

It is often assumed in the literature that engineering design is at the heart of engineering education and is what distinguishes it from other scientific areas within higher education [2]. However, although the practice of engineering design in academia and industry have tended to converge towards a Mode 2 approach, as yet there is relatively little evidence that this has been accompanied by corresponding developments in the engineering education. Jorgensen [4] argues that educational reforms have tended to focus on the development of Mode 1 model leading to a "crisis in engineering design" with "new professional groups taking over the core and more radical design tasks in companies" and he claims that "this change seems to reduce the classical engineering design departments to focus on incremental innovations and maintaining the existing products and production lines." He suggests there is a need for a re-thinking as to the "missing elements in engineering teaching" so as to prepare future professionals to face the challenges arising from contemporary technological innovation. To better understand the practice of today's engineers and its implications for education it was decided to focus initially on one national company.

In 2009 the US-based consultancy firm, Strategos, polled 186 CEOs and senior figures in leading Portuguese companies to gather data on which international and national firms they considered to be the most innovative [5]. The national company with the highest vote was YDreams, a recent startup which was created in 2000 when a group of engineers from a successful university research department at a Lisbon university felt the need to move from a university to an entrepreneurial context. YDreams has since had considerable national and international success in the areas of interactive spaces.

The authors decided to begin a pilot-study of the YDreams team to trace their historical development and see what lessons could usefully be drawn for engineering education by studying the knowledge production and practice of such an innovative organization. The key engineers in this startup were originally part of a successful university research department at the New University of Lisbon throughout the 90's in the field of environmental engineering and IT. Their Environmental Systems Analysis Group (GASA) was known for its pioneering work in a field that has since become dominated by Google Maps. In 2000, frustrated by the limitations encountered within the academic system, they effectively set aside the projects they had been working on and dedicated themselves to an entrepreneurial start-up. Their YDreams Company has since come to enjoy considerable international success in the interactive space and ubiquitous computing sectors (http://www.ydreams.com/).

A. Research questions

Is the Gibbons Mode 1, Mode 2 model appropriate to characterise the engineering practice of this group of engineers?

What can we learn about engineering practice in an innovative startup company by interviewing key players in its history?

II. METHODOLOGY

The initial methodology chosen employed what Cresswell refers to as an exploratory qualitative design [6]. This methodological approach has been used successfully in social science research for some years and has more recently also come to be adopted in engineering education research, usually as a prelude to quantitative methods within a mixed-methods methodology [7].

Accordingly, Gibbon's Mode 1 and 2 Model of knowledge production (and engineering design) were used as a basis for interviews with two of the founders of the firm and the narrative data obtained was analysed qualitatively, guided by the work of Czarniawska on narrative research methods [8].

Separate lightly-structured interviews were carried out with two senior members of the group involved in both phases: António Câmara, CEO of YDreams and former head of the GASA group and Edmundo Nobre, YDreams administrator (CFO) and co-founder. The interviewees were previously sent a brief summary of the intended case-study, which included Table 1, and invited to relate their experiences in individual interviews; they were not given specific questions to answer but rather encouraged to relate their practice in the context of the GASA research group and contrast this with their current activity in the entrepreneurial context of YDreams.

The interview transcripts were then analysed for material relevant to the Mode 1 and 2 parameters and organised under the relevant headings set out below. Subsequently a bracketing process [6] was applied to these first extracts and the transcripts were scanned for additional references to engineering practice. This produced two further observations and these are included in the Discussion section.

All extracts quoted in the paper were translated from the original Portuguese transcripts and subsequently checked for accuracy with the interviewees.

III. RESULTS

The interview data has been structured here using the Mode 1 and 2 parameters. The corresponding characterisations are summarised in the boxes at the beginning of each section with Mode 1 on the left in each case.

The narrative information relating to the university context is set out first and after that the same organizational structure is employed for the extracts describing the entrepreneurial context.

A. University Context: GASA

1) Context

academic, scientific	*economic and social applications*

António Câmara (AC): Well, we were engineers but we were doing work that was engineering/science where we were essentially emulating the approach of the physical sciences, and not really engineering as such.

(Edmundo Nobre) EN: Environmental engineers have always had a wide-ranging approach by the nature of their very general training.

AC: University groups tend to follow the logic of academia and academic publication and we had a lot of people working on theories of interaction in a way largely oriented to emulating the sciences rather than developing products. We were creating new worlds but following an existing academic model.

2) Innovation

linear	*problems are set and solved in the context of application*

AC: For example, Conservation International, which has Harrison Ford as its vice-chair, was looking for a visualization system to represent the impact of forest fires on Amazonia and resulting climate change. We submitted a proposal based on our visualization models whereas MIT Media Lab presented a demonstration created by the people who had done the special effects for the film Titanic. The difference being that they already had an operational prototype, a finished product, while we had only a complex model. So, obviously, Conservation International chose them and this episode really got us thinking, made me alter my own perspective quite radically and made me realize that however good our work was technically, we were never going to get very far in today's world using an academic approach.

So while our thinking was "ride the wave", Media Lab was aiming to "put man on the moon" and in the university context it was extremely difficult to create any kind of multidisciplinary laboratory like they had, almost impossible in fact, because there were all kinds of barriers stemming from the fact that we worked within academic disciplines. So, when we worked in the Environment Department we were expected to be dedicating ourselves to working on the environment, even if we were able to come up with something useful for automobiles ....

3) Community

disciplinary, homogeneous teams	*transdisciplinary; networked; heterogeneous actors*

AC: It was basically research work and recognition came from other researchers. In other words, our community was that of investigators the world over within our area.

EN: We were always in contact with the best work going on internationally and made a point of encouraging our graduates to go to work at the top research centers. They in turn often stayed on and tended to cite our work which gave us more visibility.

AC: Then at a certain stage we came up against other communities, ones like MIT, not the traditional scientific community, who were leaders in the field and this was something of a shock for us.

4) Orientation

explanation, incremental	*solution focussed*

AC: At GASA it was basically the kind of scholarly approach to which the majority of university courses here aspire; which means that they were very much built around knowledge, scientific knowledge, stabilized knowledge.

EN: We had the first virtual reality lab in Portugal, created for Expo 98 in Lisbon, complete with a set of instruments that were groundbreaking in world terms at that time in the area of over land navigation. We were the first country to have this infrastructure set up but it dwindled out, because policy-wise its value wasn't recognized. It was an over-ambitious project, probably ahead of its time, and like so many other breakthroughs within universities because there isn't an entrepreneurial or commercial perspective then things get bogged down and bit by bit come to a halt.

5) Method

repeatability is important	*repeatability not vital*

EN: Our objective at that time was to produce papers whereas we came to see that at other centres like MIT the object was more to produce enterprises and so they had an applied research approach and received a lot of financial support from industry.

Now MIT had funding to buy super-computers whereas we here could only invest in people, people who were capable of developing powerful algorithms which allowed us to overcome our less advanced hardware and what we achieved was certainly on a par with the best we saw at international level.

6) Quality assurance

peer-review is central	*context dependent: may involve peer-review; customer satisfaction*

AC: We were, of course, very aware of ISI indexing (…) and getting our work accepted for major conferences which are extremely competitive, with an acceptance rate of around 3%.

7) Definition of success

scientific excellence	*efficiency; satisfy multiple stakeholder, commercial success*

AC: What we basically wanted was to achieve worldwide recognition within the academic milieu through papers, articles and later books.

B. Entrepreneurial Context: Ydreams

1) Context

academic, scientific	economic and social applications

AC: I realized that to be competitive with the top laboratories in our field we would need to have professional level management, accounts, public relations … in short to have an enterprise-like structure.

EN: We had come to the conclusion that if we couldn't do what we aimed to do within the academic system then we would have to do it on the outside; so basically we went ahead and set up the company.

EN: When we first set up YDreams, the wide-ranging background of our team stood us in good stead. Now this transdisciplinary approach has paid off and in fact we have people who originally trained as environmental engineers holding down key positions in accounts, programming and project management.

Whereas in our GASA days we used to play around with ideas and ask "OK, how could we get this on the market?" now it was more in a case of "OK, how can what we do that will be important for the market?"

2) Innovation

linear	problems are set and solved in the context of application

EN: We have our R&D section, YLabs, which has a variety of functions and these include:

assisting in developing the technological infrastructure for the company itself

short-term research focused mainly on product development for our clients

long-term research which is looking to identify future paradigm shifts so that we can be right there when things are happening. In this respect, I would give the example of our work on interactive spaces which up to now has been entirely in the digital domain but as this sector has become successively more the province of large international competitors, we have to be agile and so we have been working on the application of recent innovations in materials sciences and bubble-jet technology to apply our knowhow to the development of novel interactive spaces in the physical domain.

3) Community

disciplinary, homogeneous teams	transdisciplinary; networked; heterogeneous actors

AC: Now I would say that our community is completely different: we do what we do so as to satisfy two groups of people: our clients and our investors.

4) Orientation

explanation, incremental	solution focussed

EN: We set out to adapt our practice from the GASA days to create a structure which was much more dedicated to industry, with a strong focus on applied research, one which would in turn be supported by industry. Our focus was to be on the real world products rather than on publications. We aim to be a cutting edge company.

5) Method

repeatability is important	repeatability not vital

AC: Now it really feels like we are doing engineering design and that we have left the world of classic research. One consequence of this is that now when we produce something new our first priority is to take out a patent and if we have time afterwards we may write it up in a paper. So this changes the dissemination process quite radically.

In the company we have continued to carry out research, the difference being that now we are very much more in the Man on the Moon mould. Now we really want to create products and the objective of all our research, pure or applied, is precisely product-focused. We are not at all interested in repeatability – we want to be unique, that's what it's all about!

6) Quality assurance

peer-review is central	context dependent: may involve peer-review; customer satisfaction

AC: So we are creating intellectual property, very important to appeal to clients and this has been fundamental in attracting investors in the various phases the company has gone through. To be competitive we have to bring value to the market.

7) Definition of success

scientific excellence	efficiency; satisfy multiple stakeholders; commercial success

EN: We originally wanted to leave academia and conquer the world! Success for us has two dimensions: obviously we want to become millionaires (laughs) but on the other hand we would like to be a company which helps give Portugal a strong international technological presence on a par with, say, what Nokia has in Finland. That is a company which altered their national panorama and we would like to think we could one day make a similar claim, that is to really make the difference between what Portugal is today and what it could achieve tomorrow – help to create a technology driven nation.

IV. Discussion

The data presented suggest that, although the Mode 1 and 2 characterizations can be seen as useful here to characterize in a broad sense the knowledge production activity of the group of engineers in question and to help us accompany what seems to have been a significant phase change in the work of the group, they should not be seen as an either/or way of describing the real-world activity involved.

In addition, having bracketed the previous extracts, a rereading of the interview transcripts threw up some additional comments, which led us to rethink our original model of engineering practice and reexamine our concept of what engineers actually do:

EN: Right now, I recall off the top of my head that our head of Quality, head of Research, head of Software, our top programmer and the account managers of our best accounts all come from an environmental engineering background and this pluridisciplinarity, the capacity to handle a broad sweep of areas is very valuable in a company like ours. These roles involve heading up teams where skills of dealing with both a range of multidisciplinary projects and with their commercial aspects are vital. Obviously when we get to the execution, programming, design and so on then we will call upon our specialized people for these very specific functions.

AC: What worries me is that engineering courses in our national universities don't have a tacit curriculum like you

can find at top international institutions: our graduates have the technical skill; they can solve problems but are not good at explaining them. One feels they were well trained in problem-solving but at the expense of important skills like analyzing, communicating and debating which contribute to the kind of structured thinking we need.

Noting that a significant number of engineers in the company were in posts of responsibility outside conventional engineering domains and that the CEO identifies communication skills as a priority for success, has lead us to see limitations in our original model of engineering practice which was based around engineering design and knowledge production and encouraged us to look for alternatives, particularly for models based on an empirical approach. Although the vast majority of literature on engineering practice tends to view it in terms of design or technical problem-solving [9, 10, 11, 12, 13] such models are rarely based on empirical studies analyzing what engineers do.

A model proposed by James Trevelyan of the University of Western Australia in 2009 does however address these issues [3]. The Unifying Model of Engineering Practice sees engineering as social system involving a sequence of steps common to most engineering activities and which are enclosed within a scaffold that continually guides the implementation steps towards the intended objectives. The scaffold in turn involves continual interaction between all the participants, including the client, financiers, engineers, contractors, suppliers, production and service delivery workers, technicians, regulators, government agencies, local community and special interest groups. This model grew from a longitudinal study of engineering graduates in Australia [14, 15] which showed that the majority spent less than 30% of their working time on specialized problem-solving and technical coordination emerged as the most frequently mentioned activity. The study found that graduates asked to estimate time spent on different aspects of their work estimated that nearly 60% of their time is spent interacting with other people, including working face to face, meetings, correspondence, reports and working with human-readable data in information systems and this finding would tend to give weight to Antonio Câmara's comment on the importance of communication skills.

V. Conclusion

To quote Trevelyan: "Engineering works. It could work better, however, with improvements in education and an identity in which the social and technical embrace each other with equal prominence." [3] Accordingly it is important to have empirical data on the activity of engineers in successful companies so as to achieve a good alignment between engineering education and the needs of future engineers and their employers.

Our current research, carried out in collaboration with the University of Western Australia, involves empirical data collection from engineers in YDreams and other firms considered innovative in the Portuguese context to see to what extent the Australian data and the Unifying Model are relevant to the southern European context and how this model can help adapt engineering education to the needs of tomorrow.

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Session 03D Area 1: Computer and Web based Software - Physics Applications

An application-case for derivative learning: optimization in colour image filtering

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Educational Computer Tool for Visualizing and Understanding the Interaction of Electromagnetic Waves with Metamaterials

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Illustrating amazing effects of optics with the computer

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A simulation software for sequential control

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An application-case for derivative learning: optimization in colour image filtering

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***Abstract*—Related to the notion of derivative of a function, its application to function optimization is an interesting and illustrative problem for Engineering students. In the present work, we develop an application of the derivative concept to optimize the filtering of a colour image. This implies to optimize the value of the filter parameter to maximize performance. We propose to maximize the quality of the filtered image represented by the *Peak Signal to Noise Ratio* (PSNR), which is a function of the filter parameter. The optimal value for the parameter is obtained by means of an algorithm based on the approximation of the derivative of the PSNR function so that finally the optimum filtered image is obtained.**

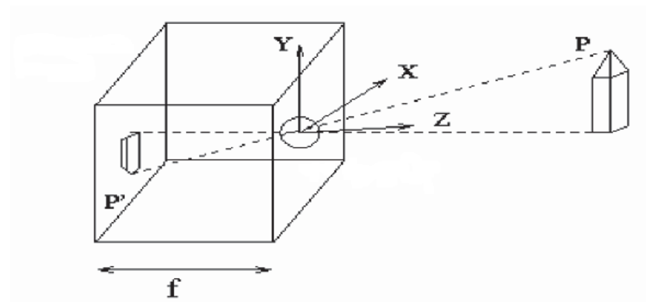
I. Introduction

Applications of calculus of maxima of one variable functions, presented to Engineering students, usually consists on finding the zeroes of a derivative which is expressed in terms of elementary functions. In some cases the numerical point of view of the calculus of this derivative is also considered. However, it is quite difficult to show a real and interesting application where the derivative plays a crucial role. In this paper we will see that the problem of optimizing an image by using colour image filtering can be reduced to the calculus of the maximum of a certain function called the *Peak Signal to Noise Ratio*.

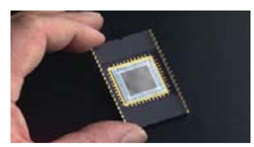
In Section II we will show some preliminaries about image acquisition and representation. Some basic notions about image filtering are also presented. The utility of fuzzy logic is introduced for filtering design. Section III describes the optimization algorithm based on the approximation of derivatives. Section IV shows simulation results, and conclusions are provided in Section V.

II. Preliminaries

An image is a $2D$ representation of the objects in a $3D$ scene which is obtained by projection of the $3D$ objects on an image plane. In digital cameras, this projection is obtained according to the pinhole camera model [1]-[3] (see Figure 1(a)): the objects, represented in a $3D$ space, are projected through a center of projection on the $2D$ image plane. The center of projection corresponds to the camera optics and the image plane is physically represented as a Charge Coupled



(a)



(b)

Fig. 1. (a) Scheme of the pinhole camera model: The object P, represented in the (X, Y, Z) space, is projected through the center of projection (camera optics) on the image plane (CCD) as the object P'. (b) A CCD sensor.

Device (CCD) sensor which captures the input radiation. The CCD sensor (see Figure 1(b)) comprises an array of $M \times N$ single light sensors. This implies that the acquired digital image is also an array of $M \times N$ single elements called *pixels* (from picture elements). In digital colour images, each pixel represents a single colour of the image. Colours are commonly represented in computers using the Red-Green-Blue (RGB) colour space. This colour space follows an additive model so that any colour is obtained by appropriately mixing the three primaries: Red, Green and Blue. Thus, each colour image pixel is associated with a tern of RGB values which represents the appropriate quantity of each primary colour that should be mixed to obtain the colour stored in that pixel.

Digital image acquisition process can be affected by many different factors able to degrade the quality of the image. For instance, deficient illumination conditions or CCD sensor malfunctions may introduce irregularities in the image also known as (Gaussian) *noise*. Other factors able to affect the

(a) (b)

Fig. 2. (a) Ideal noise-free image, (b) image corrupted with (Gaussian) noise.

image quality are, among others, transmission errors or storage faults. Figure 2 shows an ideal noise-free image and the same image contaminated with noise.

The presence of these irregularities, or noise, is not desired mainly for two reasons: (i) the perceptual image quality is lower, which is critical from the user standpoint, and (ii) the presence of noise is an important drawback for many tools of computer image analysis. Therefore, many techniques to reduce image noise have been developed in the recent years [2], [3]. Classical techniques to approach this problem are based on a linear approach. The Arithmetic Mean Filter (AMF) and the Gaussian Filter (GF) use an average operation among each pixel and its neighbours pixels [2], [3]. These methods are able to reduce image noise but they blur edges and details in the image too much. To solve this, a series of nonlinear methods were developed [2], [3],[4]-[8]. In general, these techniques are based on detecting image edges and details and smooth them less than the rest of image regions. In particular, the techniques in [5]-[8] propose to average each image pixel with only its neighbour pixels which are similar to it. Since it is difficult to differentiate between similar and non-similar pixels in a crisp way, it is more appropriate to assign a degree of similarity. The Fuzzy Bilateral Filter (FBF) [8] that we use in this work, employs fuzzy logic to assign this degree of similarity. According to fuzzy logic, the degree of similarity between two pixels is a value in $[0, 1]$ that represents in which degree two pixels are similar, where 1 means total similarity (equality) and 0 total dissimilarity. Since Lofti A. Zadeh introduced the theory of fuzzy sets in 1965, it has become a well-known area of study in the last decades. Fuzzy logic constitutes a generalization of the classical set theory which represents a gradual transition between the classical notions of outside and inside of a set. Fuzzy logic has been successfully employed in many engineering problems and many related research topics as, for instance, fuzzy topology and fuzzy metrics [9]-[13], are still active.

In most adaptive nonlinear filters, and also in the case of the FBF [8] that we use here, the smoothing capability can be tuned by modifying the values of their parameters. Thus, appropriate tuning is needed to achieve optimal performance. In this paper, we illustrate how derivatives can be used to find an appropriate setting of the λ parameter in the FBF filter. For a detail descrption of this filter, we refer the interested reader to [8]. For the purpose of this work, we just focus on the fact that the performance of the filtering process (output image quality) can be seen as a function of λ. Therefore, we propose to optimize the image quality measure represented by the *Peak Signal to Noise Ratio* (PSNR), which is a function of this parameter. The optimal value for the parameter is obtained by means of an algorithm based on the approximation of the derivative of the PSNR function so that finally the optimum filtered image is obtained.

III. Optimization algorithm description

The quality of a filtered image can be measured with several functions. In this case we will use the *Peak Signal to Noise Ratio* (PSNR) which, since the quality of the filtered image depends on λ, we define as a function of λ as follows:

$$PSNR(\lambda) = 20 \log \left(\frac{255}{\sqrt{\frac{1}{NMQ} \sum_{i \in \mathbf{F}} ||\mathbf{F}^o_{\mathbf{i}} - \mathbf{F}^\lambda_{\mathbf{i}}||^2}} \right) \quad (1)$$

where M, N are the image dimensions, $|| \cdot ||^2$ denotes the square of the Euclidean norm, $\mathbf{F}^o$ is the original noise-free image, and $\mathbf{F}^\lambda$ is the filtered image obtained after applying the FBF, respectively.

As mentioned above, we seek for the value of λ that achieve the optimum PSNR performance. To find it, we apply the following algorithm: First, we take an initial λ_0 for λ as a rough approximation to the optimum. For the current approximation to the optimum, λ_n, we approximate the derivative of $PSNR(\lambda_n)$ as

$$D(\lambda_n) = \frac{PSNR(\lambda_n + \delta) - PSNR(\lambda_n - \delta)}{2 \cdot \delta}, \quad (2)$$

where, $\delta > 0$. Now, we check whether the actual approximation to the optimum is already good enough: if $|D(\lambda_n)| < \epsilon > 0$, then the derivative at λ_n is small enough to conclude that it is very close to the optimum, and the method stops. Otherwise, we find the next approximation to the optimum λ_{n+1} from the previous λ_n as

$$\lambda_{n+1} = \lambda_n + \alpha D(\lambda_n), \quad (3)$$

where $\alpha > 0$ is called the learning parameter whose importance will be commented in Section 3, and the above procedure is repeated. Notice that, according to Eq. (5), the sign of $D(\lambda_n)$ indicates the direction in which the optimum is located and the *speed* in which the algorithm advances towards it is proportional to $|D(\lambda_n)|$.

IV. Simulation Examples

To illustrate the use of the derivative in the identification of the optimum λ for the FBF, the corrupted image of Lenna in Figure 2 (b) will be used. Figure 3 presents the PSNR computed for the image and the complete range of λ values.

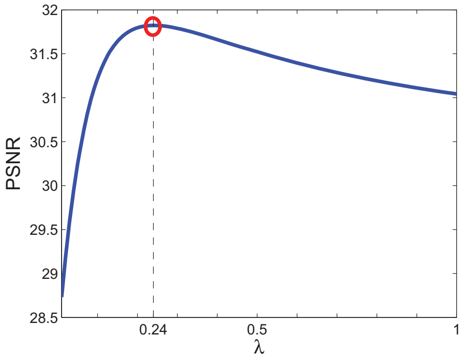
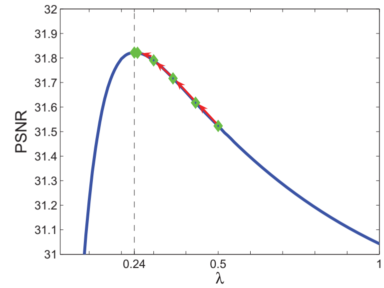


Fig. 3. PSNR curve for the complete range of λ values in the corrupted image of Lenna in Figure 2 (b).



(a)

(b) PSNR = 31.80

Fig. 4. Optimization for initial point $\lambda = 0.5$ and $\delta = 0.01$, $\alpha = 0.05$ and $\epsilon = 0.1$: a) optimization steps, b) optimum filtered image.

This figure shows that the optimum filtering performance is attained for $\lambda = 0.24$. To compute this PSNR curve, it was necessary to filter the Lenna image one hundred times - from $\lambda = 0.01$ to $\lambda = 1$ in steps of 0.01. This is a valid but computational overwhelming method to obtain the optimum parameter. Furthermore, we only obtain the optimum with a certain accuracy which depends on the step used. To improve the accuracy we need to reduce the step, which in turn means to increase the number of times the image needs to be filtered. For instance, to reduce the accuracy in one order, it is necessary to increase by 10 the number of times the complete image is filtered.

An alternative to the extensive computation used to obtain Figure 3 is the derivative-based -or gradient-based- optimization treated in this paper. Let us illustrate the use of this method with an example. The optimization will be started from the central value $\lambda = 0.5$. The optimization parameters are $\delta = 0.01$, $\epsilon = 0.1$ and $\alpha = 0.05$. The evolution of the optimization is depicted in Figure 4(a). We arrive to the optimum filtering the image only 12 times - the number of approximations of the derivative (6) times the 2 applications of the filter per approximation (2 according to Eq. (2)). Furthermore, by reducing ϵ, the accuracy of the optimum can be improved with only a few more runs. The optimum filtered image attained is shown in Figure 4(b).

The convenient choice of the optimization parameters is of paramount importance to ensure convergence to the optimum. We have already commented that ϵ controls the accuracy achieved in the identification of the optimum. In this paper, we are considering the noise-free optimization case, so that we assume that the function to optimize -the PSNR curve- is free of measurement noise. If this is not the case, ϵ should be high enough so that it exceeds the noise level in the derivative estimation.

The three parameters, δ, α and ϵ, have interrelated effects. For the sake of easy understanding, the influence of the choice of δ and α will be discussed separately, varying the parameters one at a time while maintaining the other fixed. Let us run the optimization for δ values equally distanced in the logarithmic scale over [0.001, 1] and for fixed values of $\alpha = 0.05$ and $\epsilon = 0.1$. The results are presented in Table I. The lower the value of δ, the better the derivative estimation. This is again assuming the PSNR function to optimize is free of measurement noise - it is well known that derivative estimations are highly affected by noise. Since the derivative is more accurately estimated for low δ values, the optimization arrives to higher values of PSNR. Also, we can see that the value of δ is related to the number of points or λ values in the optimization where the derivative is estimated. The higher the value of δ, the lower the number of points. Notice that if δ is too high, the optimization algorithm may not converge to the optimum. The changes observed in the optimization method due to the use of different values of δ can be easily explained in simple geometric terms. If the current value of λ is far from the optimum, high δ values result in derivative estimations of high magnitude. Therefore, the optimization is speeded up and the number of points evaluated are reduced. If otherwise λ is close to the optimum, the optimum may be included in the interval $[\lambda-\delta, \lambda+\delta]$ where the derivative is estimated. If this is the case, the magnitude of the derivative is underestimated. The higher the value of δ, the higher the interval where this occurs and the further to the optimum we may converge.

Let us run the optimization for α values equally distanced in the logarithmic scale over [0.005, 5] and for fixed values of $\delta = 0.01$ and $\epsilon = 0.1$. The results are presented in Table II. We can see that the value of parameter α is especially important for the optimization. The optimization may easily diverge if the parameter is made too high. Nonetheless, for very low values of α, the number of points where the derivative has to be estimated is much increased. For instance, for $\alpha =$

δ	# points	Attained PSNR
$1 \cdot 10^{-3}$	8	31.822
$3.26 \cdot 10^{-3}$	6	31.822
$1 \cdot 10^{-2}$	6	31.822
$3.26 \cdot 10^{-2}$	6	31.822
$1 \cdot 10^{-1}$	5	31.815
$3.26 \cdot 10^{-1}$	4	31.634
1	∞	Divergence

TABLE I
RESULTS FOR DIFFERENT VALUES OF δ AND $\alpha = 0.05$ AND $\epsilon = 0.1$ WITH STARTING POINT $\lambda = 0.5$.

α	# points	Attained PSNR
$5 \cdot 10^{-3}$	55	31.822
$1.58 \cdot 10^{-2}$	18	31.822
$5 \cdot 10^{-2}$	6	31.822
$1.58 \cdot 10^{-1}$	29	31.822
$5 \cdot 10^{-1}$	∞	Divergence
1.58	∞	Divergence
5	∞	Divergence

TABLE II
RESULTS FOR DIFFERENT VALUES OF α AND $\delta = 0.01$ AND $\epsilon = 0.1$ WITH STARTING POINT $\lambda = 0.5$.

$5 \cdot 10^{-3}$, 55 derivative estimations were needed to arrive to the optimum. This means that the Lenna image had to be filtered 110 times, 10 times more than for computing Figure 3. The best α value, so that the algorithm converge to the optimum in the lowest number of points, depends very much on the initial point - initial λ value. As a general rule, α should be set high enough for a fast exploration while not too high to avoid divergence.

V. CONCLUSION

The use of real applications of Mathematics motivates the learning process of students in several ways. In particular, most mathematical notions can be explained by use of different models. In this work we have presented a simulation model which will allow the students to relate the notion of derivative of a function and one of its applications which is optimization problems. By the simulation process described in this paper, the students will approximate the optimal value of the parameter in a function and, moreover, they will really see how appropriate is the result of this algorithm since the visualization of the output images by using a filter technique will allow the students to search for better results. This application can be used in a first semester of Calculus either as a guided practice or as an accessible research project for advanced students.

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Educational Computer Simulations for Visualizing and Understanding the Interaction of Electromagnetic Waves with Metamaterials.

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Abstract— **In contrast to ordinary materials, metamaterials show interesting properties that are not found in nature. These properties are counterintuitive and difficult to understand for the students. This work describes a series of virtual experiments that were carried out by means of an extension of the FDTD technique for modeling metamaterials. The result of the simulations was recorded and a collection of videos developed as a supplementary tool for teaching at advanced undergraduate and graduate levels. The objective is to help the student to understand the interaction of electromagnetic waves with these media by means of the visualization of the evolution in time of the physical phenomena.**

Keywords-component; educational software, visualization, metamaterials

I. INTRODUCTION

Over the last decade a great deal of attention has been paid to a new kind of media named "metamaterials". Metamaterials are artificially structured composite media with a unique electromagnetic response not present in naturally occurring materials [1].

The nonconventional properties of metamaterials were theoretically investigated by Veselago in 1968 [2], and stem from the fact that these media present simultaneously negative permittivity ε and permeability μ. However, it was in 1998 when the first possible realization of a metamaterial was achieved by the appropriate combination of metallic wires and split-ring resonators [3]–[4].

Since this first synthesis there has been an increasing interest on these media and nowadays, metamaterials are a relevant hot topic in science and technology becoming one of the fastest moving research fronts according to the Web of Science [5]. The keen interest on this kind of media is due to their exotic electrodynamic properties, such as the negative refractive index ($n < 0$), backward-wave propagation, negative Goos-Hänchen shift, reversal Doppler effect, inverse Cerenkov radiation,... and also for their important potential applications in the development of novel devices [6], perfect lenses [7], invisibility [8], [9], etc.

In general, students have difficulty in perceiving the behavior of electromagnetic waves. The situation is worsened when metamaterials are involved, since they exhibit an electromagnetic response not found in natural media that seems counterintuitive to the students.

Electromagnetic simulators have proven to be useful teaching/learning tools to provide physical insight into the phenomena under study. This goal is more easily achieved by time-domain simulators, since they emulate the progression of the fields as they actually evolve in space and time [10]-[12].

The finite-difference time-domain (FDTD) is an accurate numerical technique for solving Maxwell's equations. The conventional FDTD scheme has been successfully extended to incorporate the modeling of a broad range of electromagnetic simulation problems, what has made the FDTD method one of the most powerful and flexible numerical techniques that enables the solution of problems in the time domain [13].

In this work an extension of the FDTD technique for modeling metamaterials [14]-[15] has been used to carry out a series of virtual experiments. These experiments have been carefully chosen to illustrate the characteristic behavior of electromagnetic waves in these media. The result of the simulations has been recorded and a collection of videos has been created. The videos are intended for advanced undergraduate and graduate students and their objective is to promote understanding by means of the visualization of the evolution in time of the fields in metamaterials.

II. FDTD MODELING OF METAMATERIALS

When simulating the propagation of electromagnetic waves the starting point are Maxwell's curl equations. For two dimensional problems and for the TE_z polarization case, these equations can be written in the Laplace domain as

$$\begin{aligned} sD_x &= \frac{\partial H_z}{\partial y}, \\ sD_y &= -\frac{\partial H_z}{\partial y}, \\ sB_z &= \frac{\partial E_x}{\partial y} - \frac{\partial E_y}{\partial x}. \end{aligned} \tag{1}$$

In the Laplace domain, the constitutive relationships that characterize the metamaterials are given by:

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$$\vec{D}(s) = \varepsilon(s)\vec{E}(s),$$
$$\vec{B}(s) = \mu(s)\vec{H}(s), \quad (2)$$

where ε is the electric permittivity and μ the magnetic permeability of the medium.

Any physical realization of a metamaterial is dispersive, i.e., its effective constitutive parameters depend on the frequency. In those frequency regions where the permittivity and permeability present simultaneously negative values the medium will have a negative refractive index and will exhibit the interesting physical properties of metamaterials.

In the classical FDTD approach [13] the space and time derivatives in Maxwell's curl equations are approximated by means of second-order central differences and the computational space is divided into cells where the electric and magnetic field components are alternately distributed. This leads to a system of explicit finite-difference equations that allows us to iteratively compute the electric and the magnetic fields. The resulting algorithm is a marching-in-time procedure that simulates the actual electromagnetic waves in a finite spatial region.

The original FDTD scheme has been successfully extended to the modeling of different kinds of materials. In [14] an approach to incorporate metamaterials was presented.

In this work that extension of the FDTD technique has been used to visualize the most typical phenomena of wave propagation in these media. In particular we have considered two dimensional problems for the TE_z polarization case. The computational domain was surrounded by PMLs absorbing boundary conditions.

In our simulations, for the sake of simplicity, and in order to have a wide double negative frequency band, we have assumed that the permittivity and the permeability follow identical Drude dispersion models, which in the Laplace domain can be expressed as:

$$\varepsilon_r(s) = \mu_r(s) = 1 + \frac{\omega_p^2}{s^2 + s\omega_c} \quad (3)$$

where ω_p and ω_c are the plasma and the collision frequencies respectively. According to (3), in the lossless case ($\omega_c = 0$), for frequencies $\omega < \omega_p$ both constitutive parameters will be negative and the medium will present interesting electromagnetic properties.

III. Visualizing and Understanding Physical Phenomena in Metamaterials

A. *Negative refraction*

According to Snell's law, when a wave impinges at the interface between two media the relationship between the angles of incidence and refraction is given by:

$$n_1 \sin\theta_{inc} = n_2 \sin\theta_{ref}. \quad (4)$$

Natural media present positive refractive indices ($n > 0$), and therefore positive refraction angles. However, metamaterials exhibit a negative refractive index ($n < 0$). As a result, Snell's law is reversed at the interface between ordinary media and metamaterials. To display the anomalous refraction to the student we have designed two numerical experiments and generated the corresponding videos. In the first one we can visualize the incidence of a CW Gaussian beam on a medium with ($n_2 > 0$). As expected, the beam is refracted with a positive angle. Fig. 1 shows a snapshot of the simulation.

In the second simulation the same Gaussiam beam travelling in air impinges on a metamaterial with ($n_2 < 0$). By means of the recorded movie the student will be able to visualize how refraction is reversed, i.e., the refracted beam is on the same side of the normal as the incident beam is.

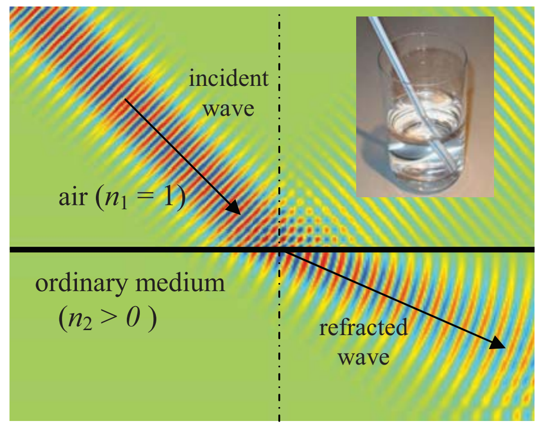


Figure 1. Positive refraction at the interface between air and an ordinary medium

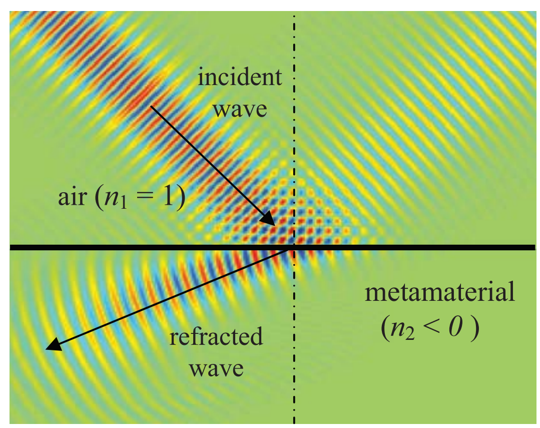


Figure 2. Negative refraction at the interface between air and a metamaterial: the light bends back from the normal.

B. *Backward propagation*

The phase velocity can be written as a function of the refractive index as

$$v_{ph} = \frac{c}{n} \quad (5)$$

where c is the speed of light in vacuum. Thus, due to the negative refractive index, metamaterials present negative phase velocity. However, the direction of the time-averaged flux of energy is determined by the real part of the Poynting vector

$$\vec{S} = \frac{1}{2}\vec{E}\times\vec{H}^* \qquad (6)$$

which is unaffected by a simultaneous change of sign of ε and μ. Therefore, in a metamaterial the energy and the wavefront travel in opposite directions (backward propagation).

For most students, it is difficult to mentally visualize the backward propagation phenomenon, since it is counterintuitive that the energy and the wavefront travel in opposite directions.

To promote the understanding of this phenomenon we have simulated the normal incidence of a wave on a metamaterial slab. Fig. 3 shows the snapshots of field propagating across a slab at two different time instants. In the figure we can see how in the metamaterial region the wavefront travels in the negative x-direction, while the power is flowing in positive x-direction, since the signal is transmitted into the second air region.

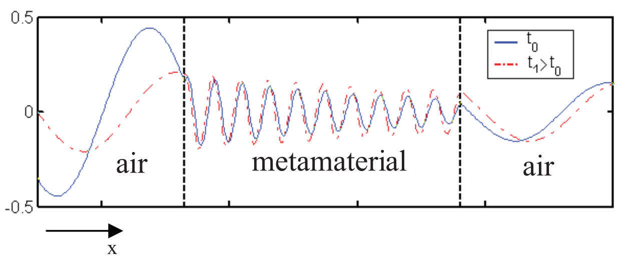


Figure 3. Backward propagation, in the metamaterial the power flows in the positive x-direction while the wavefront travel in the negative x-direction.

A static image like Fig. 3 does not clearly illustrate the backward propagation in the metamaterial slab. However, by means of the simulation movie the students will be able to visualize the evolution of the fields in time, which will help them to understand this phenomenon.

C. Pendry's lens

Another remarkable property of metamaterials is the possibility of creating flat lenses. Materials with negative refractive index refract light at a negative angle which allows a flat lens to bring waves into focus, whereas media with $n > 0$ always require curved surfaces to focus light. In fact a flat lens made of a metamaterial with $n = -1$ and thickness d, will produce two foci, one inside the slab and the other outside the slab. As can be seen in Fig. 4, for a source located at a distance d_0 from the front face of the slab the foci will appear at $d_{f1}=|d_0|$ and $d_{f2} = 2d-|d_0|$ [16].

In general, lenses introduce a phase correction to each of the Fourier components so that at some distance beyond the lens the fields focus. However for large values of the transverse wave vector these waves become evanescent and their amplitude decays exponentially so no phase correction will restore their original amplitude. As a result, for ordinary lenses, the evanescent waves are removed from the image.

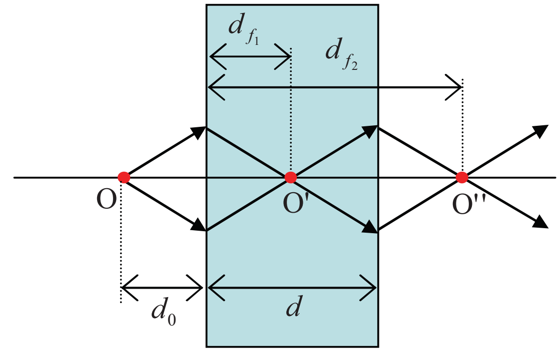


Figure 4. Flat lens: a slab made of a metamaterials with n = -1 focuses the waves producing two foci, one inside the slab and the other one outside

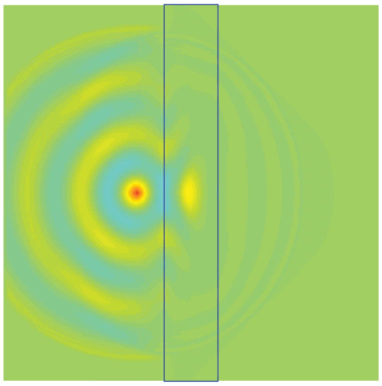
In the year 2000 Pendry [7] pointed out one of the most promising properties of a metamaterial slab. In that work Pendry theoretically demonstrated that a lens made of a metamaterial slab with $n = -1$ could restore the amplitude of evanescent waves, which may enable the development of "super-lenses" with a focusing resolution beyond the diffraction limit.

In order to show the student the behavior of Pendry's lens we have simulated a 10-mm thick slab of a metamaterial. A source is located 5 mm in front of the slab. The working frequency is f_0 = 30 GHz. At that frequency, the refraction index of the slab is $n(f_0) = -1 - j0.0011$. In Fig. 5 we can see three snapshots of the simulation. In the first one we clearly distinguish the location of the source. In the second one we can see how the first focus begins to emerge in the middle of the slab. Finally in the third image the second focus appears 5 mm behind the slab. In this last image we can also distinguish some surface waves at the first interface of the slab.

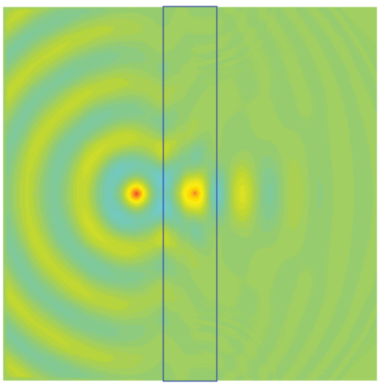
Although in Fig. 5 we can perceive the behavior of the fields in Pendry's perfect lens, it is indeed much more clearly visible when the time-domain solution is displayed. Thus, watching the simulation video the students will be able to see not only the formation of the two images by a flat lens but they will also be able to watch the dynamics of the surface waves, how they are built up and how they travel along the interfaces. It is of considerable interest that the students visualize and understand how these surface modes propagate since they are responsible for the amplification of the evanescent waves in a metamaterial slab.

D. Negative Goos-Hänchen shift

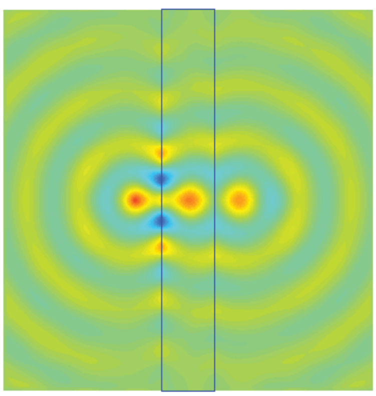
When a beam of light is totally reflected from a plane interface between two dielectrics, there is a lateral shift between the reflected light beam and the incident one. This lateral shift was predicted by Newton and experimentally demonstrated by Goos-Hänchen. However, when the beam is reflected from a metamaterial this phenomenon is reversed and the beam undergoes a negative displacement [17]. This phenomenon is schematically depicted in Fig. 6.



a)



b)



c)

Figure 5. Pendry-s lens: a) the source is located 5 mm in front of the slab, b) the first focus appears in the middle of the slab, c) the second focus emerge and surface waves travel along the interface.

To promote the understanding of this reversal phenomenon we have run two simulations and recorded the corresponding videos. The first video displays the propagation of a wave in a medium with n_1 = 9 that impinges with an incidence angle of 45º on a medium with n_2 = 3. In this situation the critical angle equals 35.26º. Therefore, total reflection will take place and the reflected beam will suffer a positive shift ($\Delta > 0$). Fig. 7 shows one of the last snapshots of the movie where we can see the positive Goos-Hänchen effect.

The goal of the second video is to show the students how this shift is reversed when metamaterials are involved. Thus if the medium 2 is substituted by a metamaterial with n_2 = -3, and we run the simulation in an analogous way we find that the totally reflected beam undergoes a negative lateral displacement ($\Delta < 0$). This phenomenon can be seen in Fig. 8.

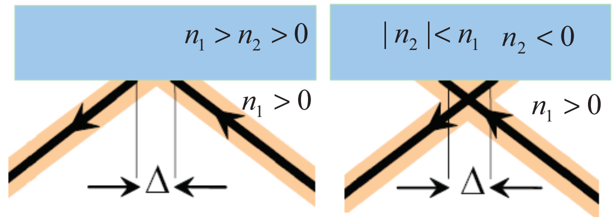


Figure 6. Goos-Hänchen effect: a) positive shift b) negative shift.

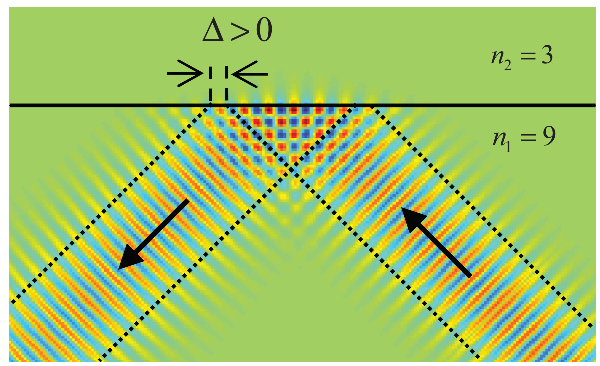


Figure 7. Positive Goos-Hänchen shift ($\Delta > 0$) at the interface between two ordinary media.

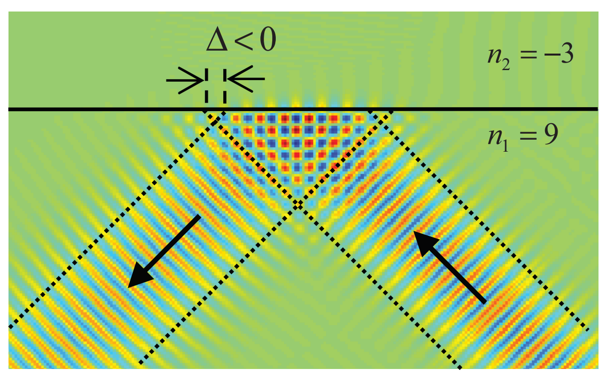


Figure 8. Negative Goos-Hänchen shift ($\Delta < 0$) at the interface of an ordinary medium and a metamaterial.

CONCLUSION

In this work an extension of the FDTD technique for modeling metamaterials has been used to carry out a series of virtual experiments. The result of the simulations has been recorded and a collection of videos has been created.

These videos provide aid in the teaching of the exotic electromagnetic properties of metamaterials, such as negative refraction, backward propagation, negative Goos-Hänchen shift, etc. By means of the visualization of the progression of the fields as they actually evolve in space and time the students will acquire a deeper physical insight into wave propagation in this kind of artificial materials.

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Illustrating amazing effects of optics with the computer

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***Abstract*—Optical systems may be complex to study, especially when they involve media with spatially varying refractive index. A fast, accurate and easy to use MATLAB code for solving the iconal equation in such media is presented. It is used for ray-tracing the propagation of light in non-homogeneous media and illustrating some amazing effects in modern physics that cannot be brought to the attention of students without the aid of numerical simulations.**

***Index Terms*—optics, ray-tracing, non-homogeneous media.**

I. INTRODUCTION

Ray optics is the branch of optics in which all the subtle wave effects are neglected: the light is considered as travelling along rays which can only change their direction by refraction or reflection. On one hand, when light propagates in media with constant refractive index, the SNELL-DESCARTES laws can be applied for implementing a fast numerical ray-tracing procedure based on a geometrical approach of the problem. On the other hand, when propagation takes place in media with non-homogeneous refractive index, the differential equation governing the propagation of light has to be solved with the aid of the computer. This contribution describes a fast, accurate and easy to use code for illustrating the propagation of light in such media, sometimes with amazing effects that cannot be brought to the attention of students without the aid of numerical simulations, or except at an expensive cost. It has been developed under MATLAB environment in the framework of an educational project, but it is general enough to be useful in most of the cases. All the lines of code are given so that they can be freely distributed and re-used.

II. SOLVING THE ICONAL EQUATION

With the incorporation of computers in the curriculum, it has become much easier to bring numerical simulations into the classroom. Since MATLAB is widely used in french universities, it is a natural choice for the authors. However, before delving into the details of the code, it is necessary to understand why the study of the propagation of light in some media sometimes raises difficulties that cannot be solved without the aid of the computer.

The iconal equation, which describes the path of the light propagating in a medium with refractive index n, is an ordinary differential equation (ODE) of the second order [1]:

$$\frac{\mathrm{d}}{\mathrm{d}s}\left(n\frac{\mathrm{d}\mathbf{r}}{\mathrm{d}s}\right) = \nabla n, \tag{1}$$

where $\mathbf{r}$ denotes the position vector of a point on the ray and $\mathrm{d}s$ is an element of length along the path. The classical approach for solving (1) is to set $f = \mathrm{d}\mathbf{r}/\mathrm{d}s$; however from the numerical implementation of a ray tracing procedure point of view it is more convenient to set $\mathrm{d}\ell = \mathrm{d}s/n$ so that (1) now reads [2]:

$$\frac{\mathrm{d}^2\mathbf{r}}{\mathrm{d}\ell^2} = \frac{1}{2}\nabla n^2. \tag{2}$$

When light is propagating in a plane, the vector equation (2) reduces to a system of two scalar equations of the second order. We therefore have in cartesian coordinates:

$$\left\{\begin{array}{lcl} \dfrac{\mathrm{d}^2 x}{\mathrm{d}\ell^2} & = & \dfrac{1}{2}\dfrac{\partial n^2}{\partial x}, \\ \dfrac{\mathrm{d}^2 y}{\mathrm{d}\ell^2} & = & \dfrac{1}{2}\dfrac{\partial n^2}{\partial y}. \end{array}\right. \tag{3}$$

As soon as the refractive index does not vary with x and y, (3) is straiforward to integrate and leads to a straight line path. When n is not uniform and according to the dependency of n with respect to x and y, it may not be possible to integrate (3) without the aid of the computer. This is why the capabilities of MATLAB [3] to quickly solve ODE is used here for studying the propagation of light in non-homogeneous media. However, since MATLAB can only solve ODE of the first order, (3) has to be rewritten:

$$\left\{\begin{array}{lcl} \dfrac{\mathrm{d}p_x}{\mathrm{d}\ell} & = & \dfrac{1}{2}\dfrac{\partial n^2}{\partial x}, \\ \dfrac{\mathrm{d}p_y}{\mathrm{d}\ell} & = & \dfrac{1}{2}\dfrac{\partial n^2}{\partial y}, \end{array}\right. \quad \text{with} \quad \begin{array}{lcl} \dfrac{\mathrm{d}x}{\mathrm{d}\ell} & = & p_x, \\ \dfrac{\mathrm{d}y}{\mathrm{d}\ell} & = & p_y. \end{array} \tag{4}$$

The MATLAB function `iconalODE` contains the final definition of the problem under study: in vector `f` are stored the values of x, y, p_x and p_y for a given value of ℓ, whereas the vector `df` returns the values of p_x, p_y, $\mathrm{d}p_x/\mathrm{d}\ell$ and $\mathrm{d}p_y/\mathrm{d}\ell$ for the same value of ℓ.

```
function df=iconalODE(l,f)
x = f(1);  px = f(3);
y = f(2);  py = f(4);
[dn2dx, dn2dy] = dn2(x,y,param);
dpxdl = 0.5*dn2dx;
dpydl = 0.5*dn2dy;
df = [px; py; dpxdl; dpydl];
```

The student has to supply a function `dn2` which should return the cartesian components of the gradient of n^2 at any point (x, y), the expression of which may depend on parameters stored in the `param` vector. The equation described in `iconalODE` is solved with the aid of the built-in function `ode45` whose integration scheme is based on a fifth order RUNGE-KUTTA approach [4]:

```
>> [l,f] = ode45('iconalODE',l,fi);
>> X = f(:,1);
>> Y = f(:,2);
>> dYdX = f(:,4)./f(:,3);
```

The solver is fed with a vector `fi` which contains the initial settings of the problem, namely x_i, y_i, $(\mathrm{d}x/\mathrm{d}\ell)_i$ and $(\mathrm{d}y/\mathrm{d}\ell)_i$ at a given starting point M_i. The values of the solution, namely x, y, $\mathrm{d}x/\mathrm{d}\ell$ et $\mathrm{d}y/\mathrm{d}\ell$ along the ray path, are returned in the array `f`: here, for convenience reasons, vectors `X`, `Y` and `dYdX` are used for storing the values of x, y and dy/dx.

III. APPLICATION IN NON-HOMOGENEOUS MEDIA

In this study, the refractive index of the non-homogeneous media satisfies the law:

$$n^2(\rho) = 1 + \frac{\rho_o^2}{\rho^2} \quad \text{with} \quad \rho = \sqrt{x^2 + y^2}, \tag{5}$$

which is inspired from previous work on relativistic particles in a KEPLER or COULOMB potential [5]. Another choice would have been to study the propagation of light in LUNEBURG lens [6], however contrary to expression (5) the refractive index would have not present a singularity and consequently the example would have been less constraining from the computational point of view and less illustrative from the point of view of the propagation of light in non-homogeneous media. However, according to the approach adopted by the authors, moving from one study to another just requires to change the lines of code written in the function `dn2` supplied by the student: this is exactly what is done in a classroom.

Coming back to (5), the region where the media is non-homogeneous will be restricted to a disk $\mathcal{D}$ with radius R. Outside $\mathcal{D}$, n will be supposed to be uniform and equal to:

$$n_i = \sqrt{1 + \rho_o^2/R^2}, \tag{6}$$

so that no discontinuity occurs at the boundary. Within $\mathcal{D}$, the components of the gradient of n^2 in cartesian coordinates are:

$$\begin{aligned} \frac{\partial n^2}{\partial x} &= -\frac{2x\rho_0^2}{(x^2+y^2)^2}, \\ \frac{\partial n^2}{\partial y} &= -\frac{2y\rho_0^2}{(x^2+y^2)^2}, \end{aligned} \tag{7}$$

whereas they are null outside $\mathcal{D}$ since n is there uniform and equal to n_i. The function `dn2` is therefore reduced to:

```
function [dn2dx,dn2dy]=dn2(x,y,param)
Ro = param(1);
R  = param(2);
if (sqrt(x^2+y^2) > R)
    dn2dx = 0;
    dn2dy = 0;
else
    dn2dx = -2*x*Ro^2/(x^2+y^2)^2;
    dn2dy = -2*y*Ro^2/(x^2+y^2)^2;
end
```

where `Ro` is used for storing the value of parameter ρ_o and `R` that of the radius R of $\mathcal{D}$.

Before solving the ODE described in functions `iconalODE` and `dn2` it is necessary to set the initial conditions of the problem. Let us consider an incident ray starting at a point $M_i(x_i, y_i)$ and making an angle α with Ox axis. In the neighbourhood of M_i, we have $\mathrm{d}x = \mathrm{d}s\cos\alpha$ and $\mathrm{d}y = \mathrm{d}s\sin\alpha$. Since at any point on the ray path $\mathrm{d}\ell = \mathrm{d}s/n$, we therefore have:

$$(\mathrm{d}x/\mathrm{d}\ell)_i = n_i\cos\alpha \quad \text{and} \quad (\mathrm{d}y/\mathrm{d}\ell)_i = n_i\sin\alpha. \tag{8}$$

Finally, the radius of $\mathcal{D}$ is set, for example, to $R = 4\rho_o$ with $\rho_o = 1$. Since the system exhibits a central symmetry, the study is restricted here to incidents rays parallel to Ox axis, so that $\alpha = \pi$, and starting from M_i located at a distance $y_i = h = 2\rho_o$ from Ox axis and with $x_i = 6\rho_o$. The following lines are the MATLAB code which corresponds to all these initial settings.

```
>> Ro = 1;
>> R = 4*Ro;
>> h = 2*Ro;
>> Xi = 6*Ro;
>> Yi = h;
>> alpha = pi;
>> Ni = sqrt(1 + (Ro/R)^2);
>> dXidl = Ni*cos(alpha);
>> dYidl = Ni*sin(alpha);
>> fi = [Xi Yi dXidl dYidl];
```

After point M_i, the path of the light is the solution of the ODE described in functions `iconalODE` and `dn2`. The complete path of the ray returned by the `ode45` solver, as described in the previous section, is represented on Fig. 1. It corresponds to the following lines:

```
>> figure(1);
>> plot(X/Ro,Y/Ro,'r-');
```

As expected, outside the disk $\mathcal{D}$, the light is travelling in

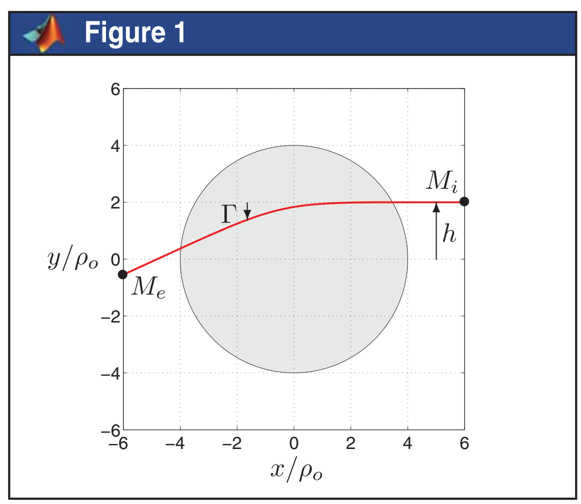

Fig. 1. An example of a ray path (in red) between points M_i and M_e. Outside the disk $\mathcal{D}$ (in grey) the media is homogeneous with a constant refractive index: the light is travelling in straight line. On the contrary, the media in $\mathcal{D}$ is non-homogeneous with spatially varying refractive index: the path of the light is curved.

straight line since the media is homogeneous with uniform refractive index (6). On the contrary, within $\mathcal{D}$ the path is curved since the light is here travelling in a non-homogeneous media with spatially varying refractive index (5). The curvature of the path is oriented towards the center of the disk $\mathcal{D}$, that is to say towards the direction of the gradient of n. The ray continuously tends towards the center without reaching it and moves away in a symetric manner with respect to the location where the distance from the center of $\mathcal{D}$ was minimal. The deviation angle Γ after travelling through the non-homogeneous media can be computed at any point M_e in the homogeneous media according to:

$$\Gamma = \arctan(\mathrm{d}y/\mathrm{d}x)_e + \pi$$

that is to say in MATLAB language:

```
>> gamma = atan(dYdX(end))+pi
```

As observed by students, h is playing the role of an impact parameter with respect to the singularity of the refractive index at the center of the disk $\mathcal{D}$ and the angle Γ that of a scattering angle with regards to the direction of the incoming ray. Shown in Fig. 1, for $h = 2\rho_o$, the deviation is about 25° with respect to the incident direction. An interesting and convenient aspect of conducting numerical simulations with the aid of the computer in a classroom with MATLAB is the capability to re-run the code with different initial settings and to obtain the new path of the light almost immediately. This is exactly what is done by the student for investigating the influence of the parameter h on the deviation angle Γ. As shown in Fig. 2, Γ varies with h in a non-linear manner. Values of Γ greater than $\pi/2$ correspond to rays which make a half turn, or even more than a complete turn, before leaving the non-homogeneous media.

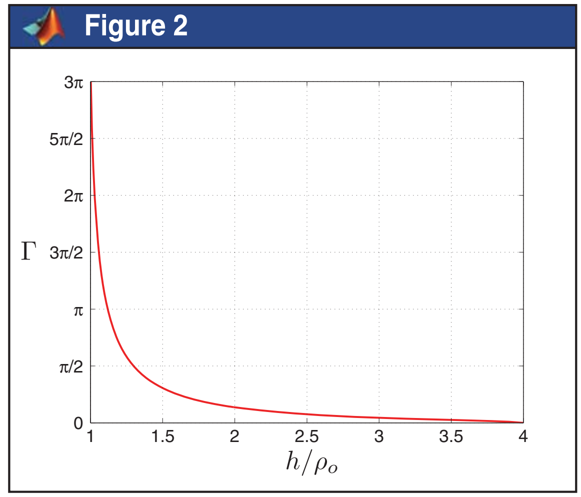

Fig. 2. Variations of the deviation angle Γ with the parameter h.

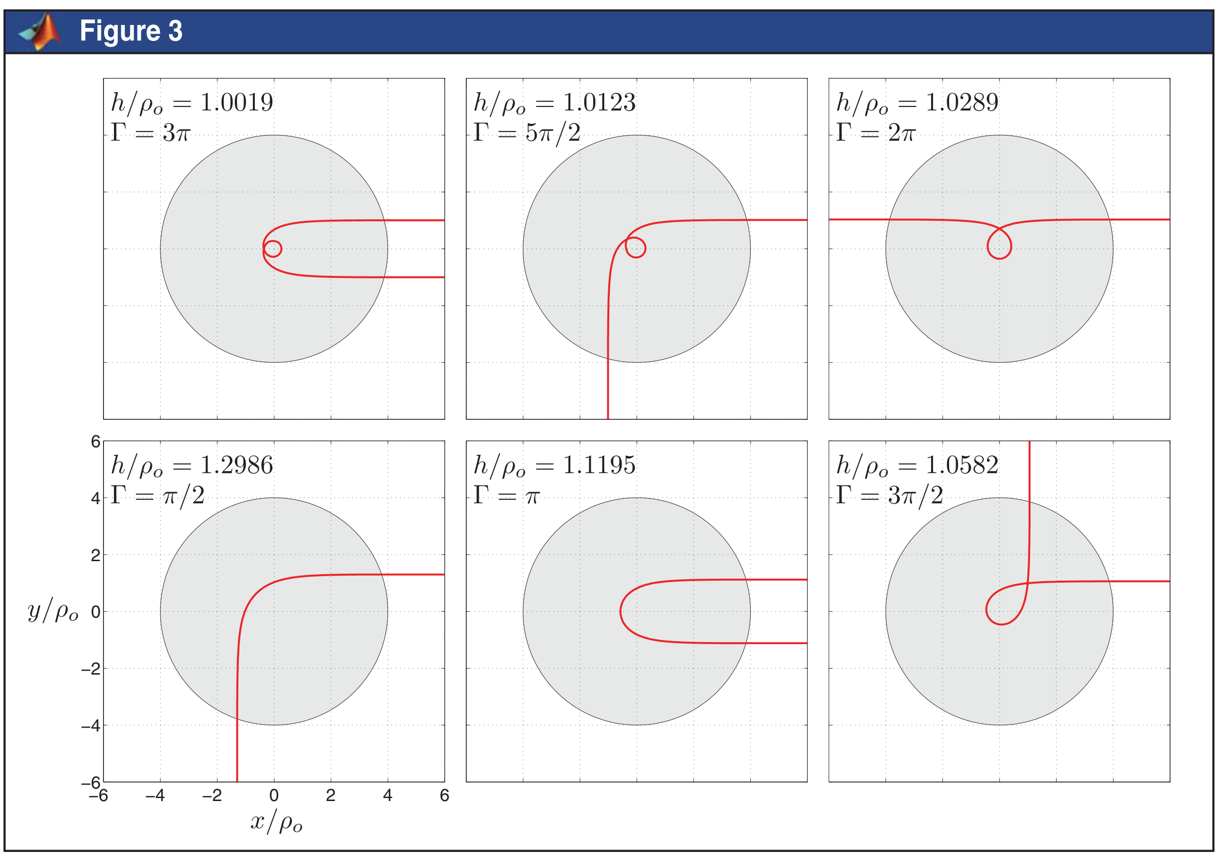

Fig. 3. Some light trajectories for various values of h.

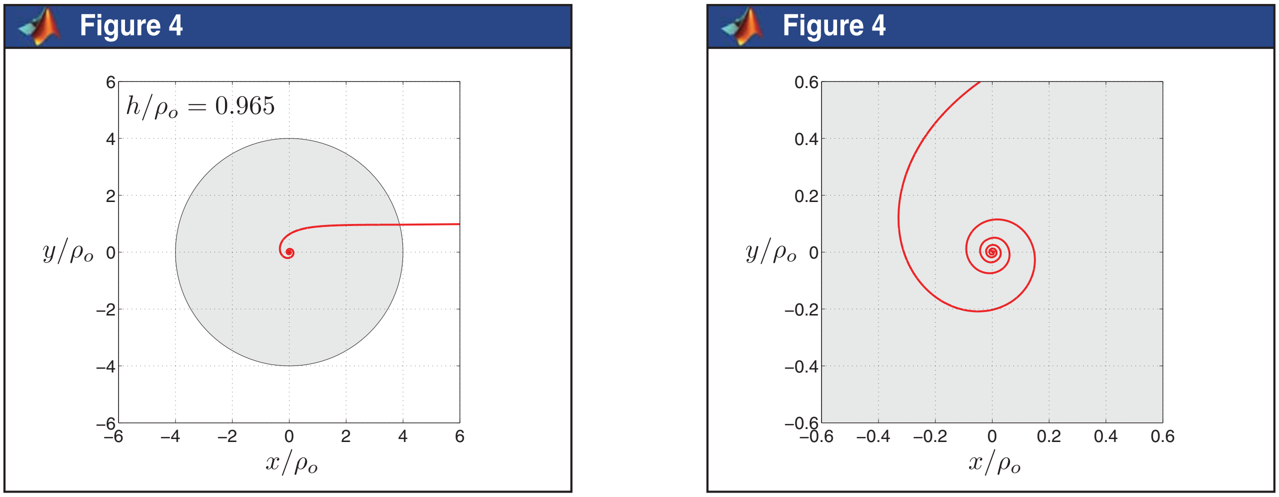

Fig. 4. Ray path for $h = 0.965\rho_o$ (central part is enlarged on the right).

Some particular situations are shown in Fig. 3 for different values of the ratio h/ρ_o.
One can think that the light can make a large number of turns before leaving the disk $\mathcal{D}$. On the contrary, below a limit for h, the path of the light identifies to that of a spiral: the ray seems to be attracted by the singularity of the refractive index of the non-homgeneous media for $\rho = 0$ and does not emerge from the disk $\mathcal{D}$. Such an amazing situation is represented in Fig. 4 for $h = 0.965\rho_o$.

IV. Conclusion

This contribution has described a MATLAB code for solving the iconal equation, especially, but not only, in media with spatially varying refractive index. The code is fast, accurate and easy to use. It has to be fed with only one function supplied by the student for switching from one study to another, the initial conditions of the problem being changed accordingly. Since the final trajectory of the light is obtained almost in real time, these initial settings can be changed at will so that an interactive study of the propagation of light is often conceivable with the computers in a classroom. In a classroom setting, the time to be allocated between the underground physics, the modeling issues and the freewheel experimentation is of course left to the teacher and may vary from one student to another. A numerical example conducted in a non-homogeneous media has demonstrated the capabilities of this code for illustrating in teaching conditions some amazing effects of the propagation of light in such media that cannot be brought to the attention of students without the aid of the computer.

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A Simulation Software for Sequential Control

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Finite state machines are a fundamental issue in a big number of fields in industry, such as sequential control, digital electronics, automated systems, automated reasoning etc. In our experience at the Universidad Politécnica de Madrid (UPM) we have found that the traditional approach of teaching the fundamentals of finite state machines through formal models is neither motivating nor allows to transmit the basic underlying principles to the student in a simple way.

Bearing this in mind we have developed a simulation software prototype in C++ programming language which uses the powerful 3D graphical libraries OpenGL and the portable Window Manager (GLUT) to develop simple 3D systems for sequential control which can be visually attractive to the student.

Keywords: Finite state machines, simulation, sequential control, PLC, physical systems.

I. Introduction

Finite state machines are a fundamental issue in a big number of fields in industry, such as sequential control, digital electronics, automated systems, and automated reasoning to name but a few.

The subject *Automatización Industrial* (Industrial Automatization [1]) is part of the current degree program of Industrial Engineering with specialization in Industrial Electronics, Automation and Sofware Engeneering imparted at the Escuela Universitaria de Ingeniería Técnica Industrial (EUITI) which belongs to the Universidad Politécnica de Madrid (UPM). This subject is taught during the fifth semester (third year, first semester) of the degree by the Department of Electrónica, Automática e Informática Industrial [2], to which the authors belong. The subject is worth 9 credits and has to be taken by all students of the programme, approximately 110 students each year.

The aim of the course is to be able to model and implement the control of industrial production systems using a PLC.
It is divided into theoretical lessons (5 hours per week) and practical ones (1 hour per week with a PLC). The subject is eminently practical and much of the time is spent in describing different technological components, communication networks, human machine interfaces, specific programming languages for PLCs etc. However our experience tells us that an extra effort should be made about the underlying model behind sequential control which is the finite state machine.

One approach to teach the basic underlying principles of finite state machines to the students at the beginning of the course is to employ simulation using as front-end SCADA (Supervisory Control and Data Acquisition) applications (as in [3]) together with a PLC simulation tool (as in [4]). This approach poses a number of problems. In the first place it becomes necessary to overcome the cost of software licenses which can be of several thousand of euros. In the second place, the level of abstraction is in many cases too close to the concrete system for an introductory course on finite state machines. Finally there is the drawback of using proprietary software as there are many practical examples in industry where finite sate machines need to be implemented in a general purpose framework.

Motivated by the above facts we have developed a simulation software prototype in C++ language which uses the powerful yet simple 3D graphical libraries OpenGL and the portable Window Manager (GLUT) to develop simple 3D systems which can be visually attractive for the student. Students are given a concrete control task and the access to the system control files. The tool allows testing the sequential control on the selected system to find out if the required specifications are met. Kinematics has also been included in the models so that erroneous control (i.e. a cylinder which exceeds a sensor limit) is also shown in the screen.

At the moment we dispose of four basic physical environments (garage door, elevator, cylinders and production chain). Each system requires a sequential control which can be implemented by a finite state machine. In each case the student needs to program the control in a plain text file written in C which associates sensor information with the corresponding control actions. After compiling the text file, the student can then watch the effect on the system. Additionally appropriate software engineering decouples the logical and graphical parts of the application so that it is relatively easy to add new elements to the graphical library which can then be employed in some or all systems.

We have used our prototype for the first time this year in the early part of the course Industrial Automatization both in theory (to illustrate the basic principles of sequential control) and in the laboratory (for physical system simulation). In the latter case we think that the prototype gives the students a better understanding of the system control requirements before they start programming the PLC. Additionally, we plan to use the tool in some of the SW courses (e.g. Industrial Informatics or Software fundamentals) to illustrate how to implement a finite state machine in a general purpose language.

The initial informal feedback of the students has convinced us of the effectiveness of our approach as the motivation of the students has become clearly visible. It is as yet too early in the year to correlate effort with understanding of finite state machines but there has clearly been an increase of hours of dedication as opposed to previous years. Additionally, personal opinions of some students have been very gratifying and encourage the authors to develop new 3D systems for future courses.

This paper is structured form here in five sections. Section 2 describes the current logical and graphical components in the application's repository and Section 3 the actual assignments which have been given to the students this year. Section 4 deals with implementation issues and includes an example of the language employed by the control function. Finally Section 5 presents conclusions and future work.

II. System Repository

At the moment we have implemented 4 systems in the 3D repository: a lift, a manufacturing line, a garage door and a pneumatic cylinder working table. Kinematic and logical simulation is provided. For example, if a motor is not stopped when it reaches its limit, it will break and not work any more. User interaction is provided by buttons and edit boxes in the interface. We will describe each system in turn.

A. Lift

Figure 1 shows the interface of our 3D lift in the repository. The system has the following inputs:

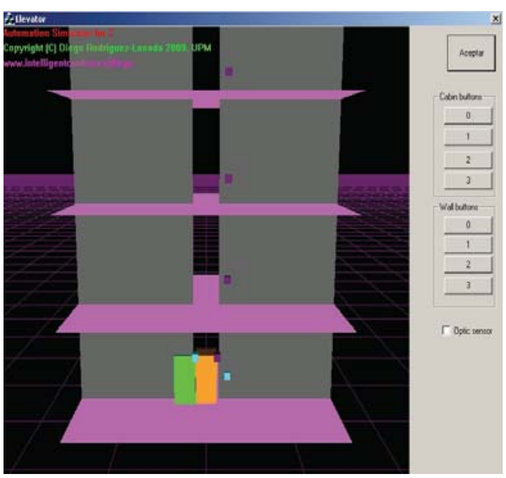

Figure 1. Interface for the 3D lift

- Cabin buttons and outside buttons to indicate the floor chosen by a potential user.
- An optical sensor which detects that a person is entering the cabin (this makes the user appear on the screen).
- A sensor at every floor to indicate the position of the cabin. These sensors change color to blue in the 3D simulation when the cabin is detected.
- Sensors that detect whether the cabin door is open or closed

Control actions are reduced to moving the cabin upward and downwards as well as opening and closing the door.

B. Manufacturing line

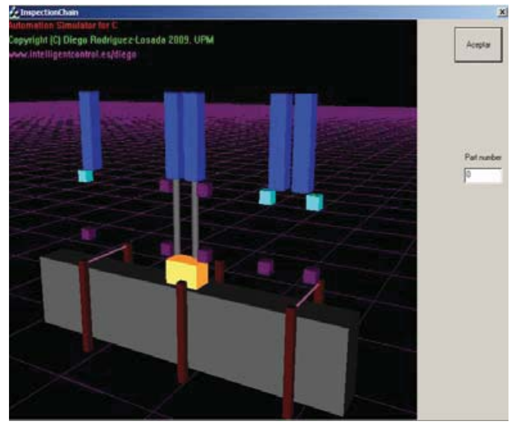

Figure 2. Interface for the 3D manufacturing line

Figure 2 illustrates our 3D manufacturing line made up of 3 different stations. A product (or subproduct) moves along the chain and can be attacked in one or both of the last two stations. In the first one (which is obligatory for all products) a code with instructions relative to the last two stations is read. The user enters this code in the edit box at the right of the screen and clicks on the 'Accept' button to start the 3D simulation.

The system has the following inputs:

- Beginning and end induction sensors for all cylinders in the different stations.
- A bar code scanner which reads the code number of the product (inserted before simulation by the student in the edit box).
- Three presence detectors, one for each station.

Control actions include compression and expansion of all cylinders (two in the last two stations and one with the bar code scanner in the first one) as well as the line movement (forward and backwards).

C. Garage door

Figure 3 shows two different views of the 3D garage door in the repository. The upper view corresponds to the initial state of the system: the garage door is closed and the system is waiting for a car to arrive. In the second view a client comes and the door is opens to his request. The entries for the control are in this case:

- An optical sensor to detect the presence of a car. This is simulated by a red line which crosses the screen in the upper view.

- An overcurrent detector which turns on the red light placed in the top left corner of the door. The event is simulated by a checkbox in the right hand side of the screen.

- Sensors which detect that the garage door is open or closed.

- Two ways of opening the door for a potential user: either using a key or a remote control. These two events are simulated by two push buttons in the right hand of the screen.

- A reset event which leads the system to its initial waiting state (i.e. the door closed and the emergency light closed, assuming the optical sensor detects no car).

Control actions include the emergency light activated by the overcurrent sensor as well as the opening and closing of the garage door.

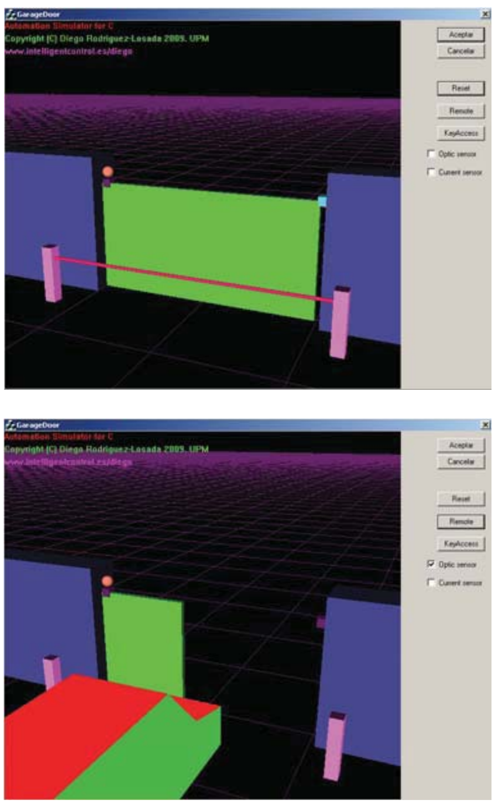

Figure 3. Two different views of the 3D garage door system.

D. *Pneumatic cylinder working table*

Figure 4 shows the 3D pneumatic working table available in the system's repository. It contains three double effect cylinders which expand and compress according to the controllers instructions attacking a piece situated at the centre.

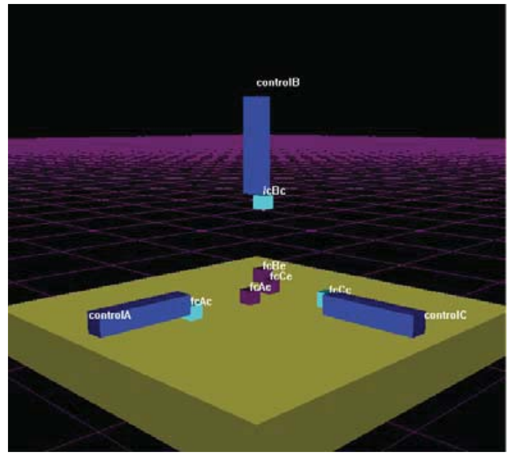

Figure 4. The 3D pneumatic working table

The inputs of the sequential control program are the following:

- Sensors to detect expansion and compression of all cylinders.

- A 'Start' button simulated by an equivalent push button in the right of the screen.

The system pre-actuators are three electro-pneumatic valves of two positions which allow expansion and compression of the cylinders.

III. ASSIGNMENTS

In this first course using the simulator we have asked the students to implement any reasonable control function for the four systems currently available (i.e. according to common sense semantics and avoiding the kinematic error models). It is to be noted that the systems, in spite of their apparent simplicity, are already flexible enough to allow for a wide variety of controlling schemes with different levels of difficulty.

A possible assignment for the manufacturing line is to assume that the bar code in the product (read in the first station) tells the controller that the product needs to stop at the last two. Another possibility would be to assume a stoppage in a different order (i.e. first in the last station, then back to the second and then once more to the first). Additionally, the cylinder expansion-compression sequences at each stop could depend on the concrete sequence read by the bar code scanner etc. Similarly, the lift could be programmed in a standard way or it could prioritize the latest order and similar variants can easily be found for the remaining systems in the repository.

Before you begin to format your paper, first write and save the content as a separate text file. Keep your text and graphic files separate until after the text has been formatted and styled. Do not use hard tabs, and limit use of hard returns to only one return at the end of a paragraph. Do not add any kind of pagination anywhere in the paper. Do not number text heads-the template will do that for you.

Finally, complete content and organizational editing before formatting. Please take note of the following items when proofreading spelling and grammar:

IV. IMPLEMENTATION

The tool has been implemented in C++ using the Visual Studio development kit, and is currently only available for Windows platforms. The system repository employs the 3D accelerator graphical libraries OpenGL (which come in the software development environment) and the portable Window Manager (GLUT).

The development process has strictly followed the object oriented design (OOD) paradigm and engineering software techniques have been applied to decouple the graphical interface from the logical parts of the system (to the extent of being compiled in a separate library). The graphical representation of the different systems is broken down into common parts (i.e. objects which encapsulate the drawing information of light bulbs, sensors, doors etc.) all of which share a common virtual interface. This makes the tool much easier to manage and, more importantly, allows building a repository of common elements which may then be employed in any new control system added to the repository.

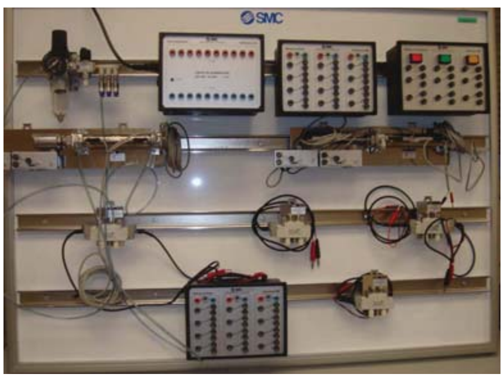

Figure 5. A two cylinder workbench used in practical lessons.

Adding a new system to the repository becomes a very easy task if it uses the components already defined in the repository. An example: the department uses in some of the practical lessons a two double effect cylinder pneumatic workbench (see Figure 5). It employs electro-pneumatic valves as pre-actuators to compress and expand both cylinders and uses different types of sensors to detect end of expansion and compression. The task is to program a PLC to produce a pre-defined sequence of expansion and compression of the cylinders. A more detailed description is available at [4].

It took only a couple of hours for one of the tool programmers to implement a very simplified, but yet again useful, simulated system of the workbench and add it to the repository. The system had only the two cylinders with sensors to detect expansion and compression and two state valves which had already been defined and employed in the four previously described systems.

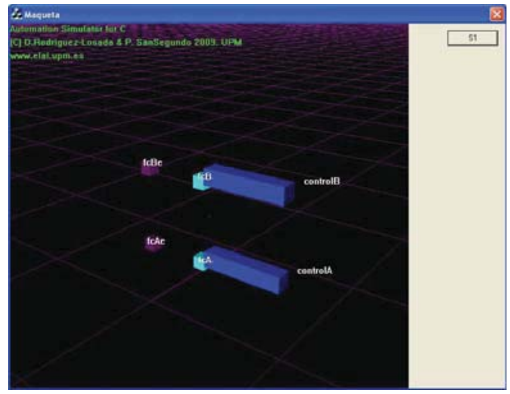

Figure 6. A two cylinder workbench

However, it could already be employed to define different kinds of assignments for the students. The graphical interface of this workbench is shown in Figure 6.

This year the students were assigned four different software projects which shared a common workspace. Once the finite state machine program (which must be written in C) is implemented, it is possible to compile the particular project with the new control function and simulate the system. Figure 7 gives a partial example of a typical control function that the student must implement. The declarative data defining the identifiers for sensor entries and actuators at the top of the file is already given to the student. The finite state machine program is encapsulated inside the definition of the control function (void *control* () in the figure) which is initially empty.

```
#include "control.h"

//Inputs
bool S1;
bool fcAe,fcAc;
bool fcBe,fcBc;


//Outputs
int controlA;
int controlB;


int estado=0;

void control()
{
    if(estado==0)
    {
        if(S1)
        {
            estado=1;
            controlA=1;
        }
    }
    if(estado==1)
    {
        if(fcAe)
        {
            estado=2;
            controlA=0;
            controlB=1;
        }
    }

    //...
```

Figure 7. Part of a typical control function for a system in the repository.

V. Conclusions

This is the first year that the tool is being tested and, as yet, it has not been possible to assess the overall effect on our students. The tasks given to them related to the software tool have been included as part of the requirements needed to pass the practical exam. We do have at the moment some personal very positive feedback from some of the pupils which would indicate that the approach taken is a step forward in the correct direction. At the end of the semester it will be possible to have a better formed opinion to this respect.

Further work in the near future will focus in developing new components for the repository (i.e. valves, pumps) and building additional system models.

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Session 03E Area 1: Wireless, Mobile and Ubiquitous Technologies for

Development of a mobile learning framework for analog electronics course

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M2Learn: Towards a homogeneous vision of advanced mobile learning development

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Adaptive Ecology M-Learning for National Park Based on Scaffolding Theory

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Development of a Mobile Learning Framework for an Analog Electronics Course

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Abstract— **With the growing popularity of mobile devices, several projects for mobile learning courses have been developed. Those equipments allow a superior portability and accessibility of the learning courses. In this context, the present paper focuses on the development of a mobile learning framework for an analog electronics course. This course was designed as a supplementary mean to the classic analog electronics courses. The course project consists of several interactive multimedia modules. At the end of each module, students have several oriented questions to answer. The set of answers, in SMS format, gives feedback to the teacher about the learning process. Another module, that is under development, is responsible for storing and managing the answers in a server, where all the results from students are processed in a competitive learning based methodology application.**

Keywords- Mobile learning environment, mobile devices, analog electronics course, competitive learning

I. Introduction

There are many different teaching/learning styles and methodologies described in literature. We can find differences in students' preferences in learning through experiential or concrete instruction, as well as we can find those who prefer collaborative activities to others with a competitive basis, and vice-versa. The style of an evaluation is also a key factor for the learning process of a student, because it determines the study procedure until the assessment moment.

As a complement, new technologies and methodologies have been used in order to allow students to learn in and outside the traditional classroom. E-learning systems enhance the possibility for students to attend lessons in remote locations, at a physical distance, being able to be at any place and to communicate actively by means of computers and networks. Being important that students have always the possibility to acquire their knowledge through traditional ways, balanced blended learning, combining e-learning and the classroom ambient learning, is a good solution for specific courses, if not for all.

However, mobile learning (m-learning) is, at the present, more innovative and student centered, concerning in the use of mobile devices, like cell phones, Personal Digital Assistants (PDAs) and smart phones. M-learning can be defined as "the exploitation of ubiquitous handheld technologies, together with wireless and mobile phone networks, to facilitate, support, enhance and extend the reach of teaching and learning" [1]. M-learning is a relatively recent concept, but by our group experiences, and by others described in literature [2, 3], it has been motivating students and teachers, representing an effective pedagogical method as any other conventional learning method. Nevertheless, the real problem with the concept is still the quest for an efficient and suitable adaptation of the courses contents to means with clear restriction factors [4]. The former restrictions are basically visual, technological and social (SMS costs, among others), which are mentioned in several works, measuring generally the impact of the handheld mobile devices in our society [5]. Therefore, in these days, the challenge for teachers is to prepare new courses based in a methodology that embraces the potential of the mobile devices and faces their restrictions. Innovative supporting frameworks should be implemented to accomplish that task. In an initial phase, these frameworks can be directed to specific courses, but they should be extended to accommodate more generic scenarios, being prepared to support almost any course.

The study of analogue electronics is fundamental in an electrical engineering course. Generally, in these courses, classical teaching uses textbooks as the main element. However, the use of textbooks is very limited, too flat and static. Therefore, in this new technological context, it is important to develop new m-learning tools for these courses. With that in mind, a new m-learning framework for the analog electronics course was developed at Superior School of Technology of Setubal (Polytechnic Institute of Setubal). The initial course material has been adapted to the m-learning environment and new contents were added, enriched with animations and interactive examples. Besides the traditional theoretical lessons, and laboratory practices, we propose the use of this m-learning system to reach a wider blended learning methodology, which also includes a Web-based module.

The current paper describes the course, which we consider original and innovative in the area of application, and the main points of the supporting computational framework development. The presented approach includes a competitive learning module, applied to the usual individualized and cooperative settings. It is essential for the growth of our students facing a very competitive global society.

This paper is organized as follows. In Section II, we introduce essential mobile and competitive lines that support some taken options. Section III presents related work regarding analog electronics course and mobile learning projects, while the course features description is presented in Section IV. Section V is dedicated to the presentation of the developed MoCoL framework and to the technology solutions used for that. Finally, in Section VI, conclusions are made and future work is presented.

II. Mobile and Competitive Learning Principles

Nowadays, mobile devices are essential tools for our daily living. With the evolution of their technologies, we see people adapting more easily to the use of the devices. According to [6], the mobile revolution is already here. "Wherever one looks, the evidence of mobile penetration and adoption is irrefutable…". "No demographic is immune from this phenomenon".

At the same time, with the evolution of the available functionalities, it also increased the diversity and capacity of multimedia options and wireless communication technologies of the devices. Seen as small computers, these devices can support diverse lessons, display animations for any kind of contents, be used for polling and testing, serve as a gateway to larger learning resources, among much more options.

With the fast growth of wireless handheld and mobile devices sales (Fig. 1), it has started to rapidly emerge the m-Learning concept as a new instructional method. M-learning is characterized by mobility and accessibility, since it focuses on the use of handheld mobile devices. These equipments have become very popular, especially among young people who use them not only for communication but also as a tool for other activities. There are almost one and a half billion mobile phones in operation around the world, and a large percentage of them are in the hands of students. In the coming 10 years, whether educators want it or not, more and more students will bring computing devices into the classrooms. In addition to the ordinary mobile phones, these devices can even be netbooks, notebooks and mobile music players, among others.

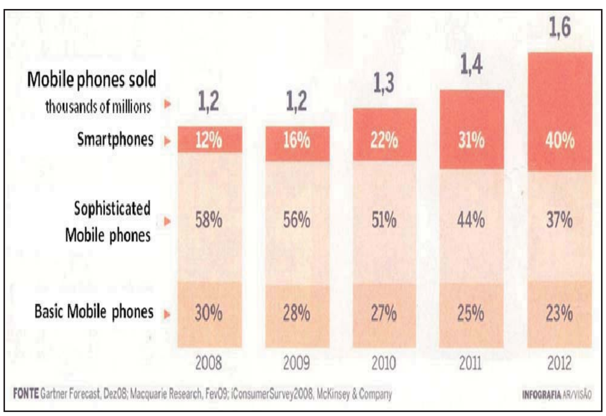

Figure 1. Number of mobile phones sold per year, worldwide [7].

For the development of the proposed project, it is important to have in mind that sophisticated and smart phones are increasing their sales in comparison to the basic cell phones (Fig. 1). Additionally, looking to the table present in Fig. 2, it is possible to establish a guideline between those sales and the increased use of advanced functionalities in mobile phones. These are important arguments, because the mobile application of the present work uses multimedia content and some connectivity options. Therefore, this is considered as a positive factor since the probability of finding devices with capabilities for playing lessons and testing contents is high, being excellent to the production of mobile applications with higher performance and better multimedia content.

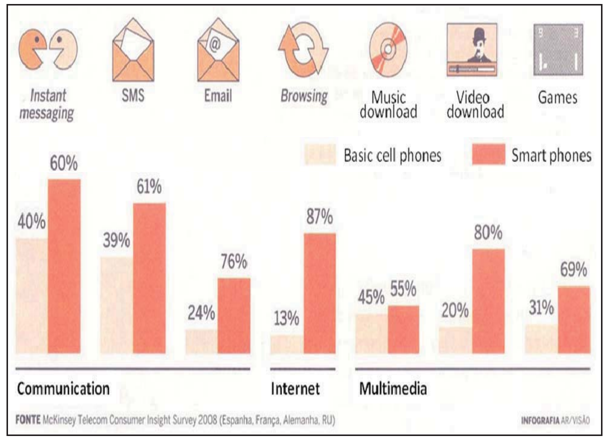

Figure 2. Advanced functionalities used in basic phones and smart phones (adapted from [7]).

As far as the use of these tools in education is concerned, not all courses are suitable for m-learning environments, but short courses are considered suitable for this kind of learning [8]. The use of quizzes, glossaries and the interaction with tutor and other peers may satisfy a wide range of needs and aims on behalf of students. Communication can be made through e-mails, SMS and MMS, and it is important for students to have feedback about their progress [8].

Johnson and Johnson suggested that an effective classroom must have the right mix of cooperative learning and competitive learning (along with individualized learning) [9]. Cooperative learning encourages students to work with and learn from each other. Alternatively, a competitive learning implementation places students against each other competing for best results [9]. For example, if a student gains a point, his competitor does not win anything. In a competitive setting, students judge their abilities to master content and knowledge relative to their competitors. In the business world people often work on a variety of team settings and cooperative activities. The context of the classroom should provide to students training for the business life and offer them some insights regarding competitiveness at work. The cooperative aspect of these set of activities may also offer a better learning environment to students. The cooperative component embedded into competitive learning represents a potential complement that may help to engage students. Once they are faced against each other, their competitive instincts can encourage them to increase their engagement in the learning process. Students who initially may not be inspired by the content may begin to be interested once they have to compete, seeing that like a game. Students must be prepared for all the adverse situations in an increasingly competitive workplace environment that they will face after finishing their graduation.

III. RELATED WORK

This section presents interesting related work, although we did not find m-learning systems delivering the pretended analog electronics contents.

With the rapid development of ICT systems, new educational opportunities and instructional methods appeared. Therefore, several e-learning tools have been developed to enhance the learning process in analog electronics courses [10, 11, 12, 13, 14]. However, these solutions do not have modules directed to m-learning, with the presentation of the functionalities and features required by our proposal.

It has to be noted that, nowadays, m-learning is a very active research field, with the development of important and interesting projects. In [15], Frohberg et al. made a deep and critical analysis of mobile learning projects published before the end of 2007. Mobile learning is rapidly growing from a set of research projects into worldwide deployment of services for classrooms, field trips, workplace training and informal education, among other areas. Major projects have concentrated on the generic platforms development for m-learning and explored new supports for a kind of technology-mediated learning across locations and life transitions [16, 17]. Smaller projects are more directed to develop new pedagogical solutions for specific cases and to explore how learning on handheld mobile devices interweaves with personal interests and individual learning needs [18].

In relation to platforms, the following projects support the implementation of specific mobile and wireless applications for mobile devices. It is important to know projects like MOBIlearn [19]. It pretends to deliver a generic m-learning architecture to support creation, brokerage, delivery and tracking of learning and information contents, using ambient intelligence, location-dependence, personalization, multimedia, instant messaging (text, video) and distributed databases. Another proposal, MADEE [20], is an execution environment and application development tool that supports and makes easier the development of mobile and wireless information systems that run on handheld devices, allowing communication and information sharing among users in an organization. Other older examples are: the Sync a Java framework [21] that allows asynchronous collaboration between mobile users; Rover [22], a framework for building mobile applications based on flexible client/server architecture; and LIME [23], a middleware package written in Java that supports mobile application development and coordination.

An interesting application of m-learning has been carried out by the Standford Learning Lab for the teaching of the English language [24]. Quizzes, glossaries and interactive audio-files were sent to students to improve their pronunciation and language competencies/skills. Interesting to us is that two other language experiences were followed for the acquisition of English vocabulary and idioms on mobile devices. The first one does it through SMS and the second by means of videos. Another application of mobile learning in the study of languages is Pocket Eijiro [25], an English-Japanese, Japanese-English dictionary, which presents some interesting features.

On the other side, the Moop [26] m-learning environment was developed for use in primary school at the city of Oulu, Finland. Moop has an interactive application for use in situations where primary school students take use of a cell phone to analyze their surroundings and to communicate within groups. The system supports the process of inquiry learning, during which a user outlines her thoughts on the current topic, collects information from the surroundings and reports the findings to the system. The HandLeR project [17], one of the oldest, is an attempt to gain an in-depth understanding of the learning process in different scenarios with the evaluation of a handheld device. The system is also "...intended to support children to capture everyday events such as images, notes and sounds, to relate them to web-based learning resources, to organize these into a visual knowledge map and to share them with other learners and teachers" [27]. This kind of systems promotes learning in complex scenarios where learning goals depend on a contextual factor.

Another system, related with context, is "Contextual Cues" that lets students, who have attended a lecture, to receive a copy on their mobile phone of key points that the teacher labels as important, which should be reviewed later [28]. To support this, a plug-in or application installed on the teacher's Bluetooth-enabled computer would make it easy to highlight important points in the teaching material. During the presentation, the broadcasting of the key points together with a timestamp takes place in parallel with the presentation of the related material.

Regarding quiz systems oriented for mobile devices, there are several commercial and free options that are interesting for our study. Moodle for mobile tests [29] is a module to execute Moodle questionnaires using CHTML (compact HTML) in compatible mobile phones with i-mode technology. Interactive test is a module of an m-learning system [30] specifically developed for use in Java-enabled mobile devices. Go Test Go's [31] is a commercial quiz system designed to be used in Java mobile phones which provides a great selection of quizzes about several areas. Finally, Quizzler [32] is a commercial product designed for PC, Palm and PocketPC platforms and provides a collection of tools (quizzler reader, quizzler software maker and quiz library).

IV. MOBILE COURSE FEATURES DESCRIPTION

The goal of this project is the implementation of an m-learning tool for the teaching of the analogue electronics basic subject. The purpose of this solution is not to replace the traditional teaching methods, but to create a complementary tool in order to improve the student's interest, motivation and the resources availability in any place, at any time.

The m-learning analogue electronic course consists in several interactive modules. The contents of the modules cover the following main topics:

- Semiconductors theory
- PN junction theory
- Diodes and applications
- Transistor and applications

The contents were developed in order to put an emphasis on demonstrating and assisting each theoretical concept with a practical application. Another important feature is the use of images and multimedia animations. As an example, Fig. 3 shows an animation about the semiconductor theory. With this image, students can see the movement of the electrical charges inside of the NPN transistor.

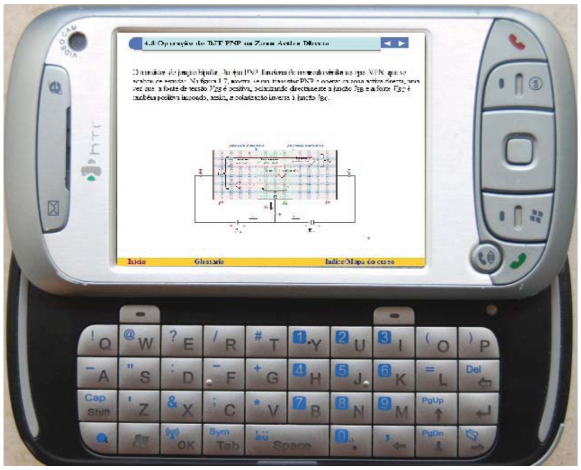

Figure 3. Animated figure of a NPN transistor (with descriptions).

Interactive figures are also essential for the understanding and motivation of the students. So, several interactive figures have been developed for this course. Fig. 4 shows an interactive circuit for the half wave diode rectifier with an output capacitor in parallel with a resistor. Students can change the capacitor value and verify the waveforms and at any instant if the diode is on/off.

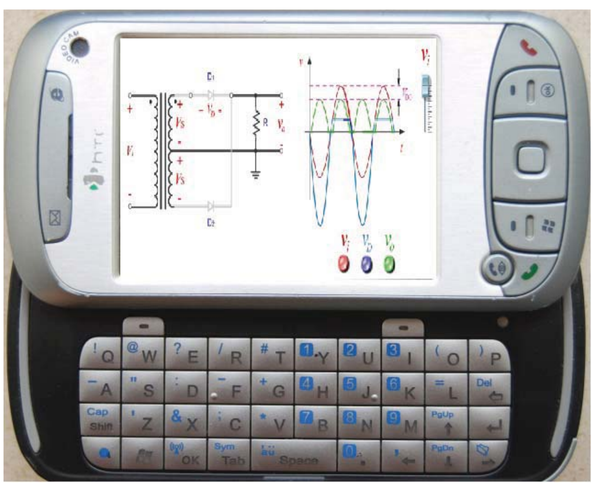

Figure 4. Interactive figure for the half wave diode rectifier (only animation).

Fig. 5 shows another interactive circuit that has been developed to explain the full bridge rectifier that uses a transformer with a center-tapped secondary winding and two diodes. With this circuit, students can change the amplitude of the input source voltage and select the waveforms that they want to see.

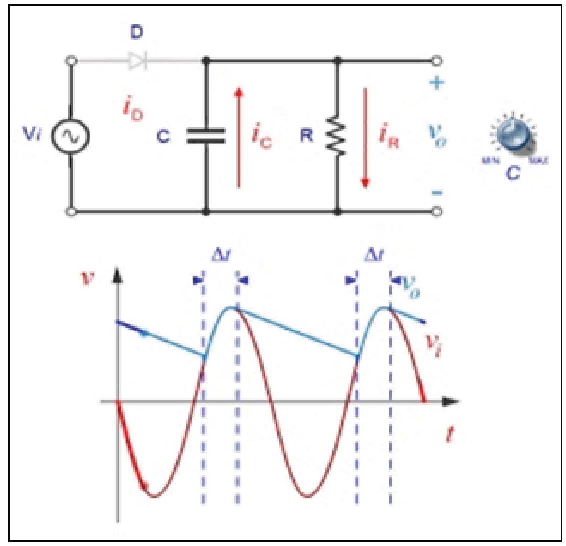

Figure 5. Interactive figure for the full bride diode rectifier.

One important feature associated with the figures and interactive animations is an option for comments. This way, students can make annotations and give feedback about those contents. With students' annotations, teachers can verify if those figures and interactive animations are clear or if they have to be improved. From those comments, teachers can also have some information about the student's knowledge. When students select the option to give feedback, an SMS will be sent to the teacher with the annotations.

In order to provide to the student an evaluation of his knowledge progress, at the end of each module there are several quizzes about the module. This also can help the teacher to verify the student's progress. At the end of the evaluative quizzes, if possible, an SMS is sent to the teacher, informing about the results to the questions. In case of failure, the student must start again the lesson. New quizzes will also appear and, in order to avoid the same questions, there is a large variety of XML quizzes that are generated from a teacher contents manager application.

The lessons are simple in order to avoid excessive information for students. However, in several pages there is an option called "to know more". So, the amount of information presented to students is adapted to their needs.

A. CL Competitive Learning Module

The competitive module implements a competition where the mobile students are selected to participate in a tournament similar to the well known UEFA® football champions league (CL), with a groups' stage and a knockout phase. This module is under development, being almost finished and in a phase of integration in the platform system.

For the competition, the students use the mobile device client application to answer to quizzes like the aforementioned ones for the auto-evaluations. One game is composed by a randomly generated quiz, being "played" by a student against an opponent and the clock. At the end of a game, the answers are automatically stored in the mobile device and sent to the server. The mobile application knows the games' results of the corresponding user/student, but the central CL application of the MoCoL framework (Section V) needs to have access to all the quizzes results, from all users. So, every now and then the applications must be synchronized with the central system, with the connection being made automatically at distance or established in the classroom. The framework automatically evaluates the obtained answers for the proposed game, elaborating the classification and managing future games.

The competition can take place for several sessions (lessons, marked days, etc.) and a teacher can configure it choosing, for example, the beginning time of the different group games, the level of the games (quizzes to be answered), the competition mode (auto-evaluation/training, assessment, or friendly), among other parameters. One additional parameter is the submission type of the results, which can be through the normal option or sending an SMS to the teacher at the end of the game.

Additionally, in the future, it will be possible for a student to submit to the database, and for a CL edition, quizzes questions to be answered by his colleagues. This is one of the most interesting functionalities in our methodology, since this can improve the learning performance of a student which has to find and know more exercises.

V. THE MOBILE AND COMPETITIVE LEARNING (MOCOL) FRAMEWORK

The present section presents the MoCoL framework, highlighting the main requirements, the supporting architecture, the development of the course mobile application and technologies used in the implementation.

A. Requirements

When implementing a new methodology and designing a framework like the one presented within this work, first, we have to establish some principles and requirements. Therefore, to support and complement the course lessons it is highly desirable to have a computational system working with the following main goals: to allow the mobile learning to run in a motivating setting; to flexibly the timetables for learning in order to complement classroom lessons, which can be important for workers; to allow the student auto-evaluation; to allow recovery modules in order to give to all students the same opportunities; and to add the option to be used interactively in different kinds of classroom lessons.

MoCoL uses four main end-users groups as system requirement. They are students, teachers, administrators and even parents. Students are the main end-users because they get numerous benefits from the system. The system provides notes and tutorials for the students to learn more about the subject. Besides, it has information about other links related to the chapter.

Teachers can use the platform as a teaching tool by looking at the lesson, tutorial and other links that will be provided by the system. Besides, teachers play an important role providing questions to the quizzes section. The system provides a function of auto-calculation, making the quizzes more or less difficult, according to the integration of questions. The teachers have to update the chapters' contents. Teachers also receive email from the student or his parents regarding his performance. Thus, the system provides good relations between teachers and student as well as with their parent(s).

The administrator has the role to access most of the functions in the system. This is because he has to update and configure the system to meet the requirements of the teacher.

Parents use MoCoL to guide their children's performance in the course. They can check how many times the children have accessed their study material and what exactly they do when entering the system. The parents will have a log file in their module for this purpose. Besides, the parent can contact the teacher if they want to ask anything regarding their children's performance.

B. System's Architecture

The architecture of the global system is the typical client-server solution with the two-tier separation (Fig. 6). The clients are the following: a web tool (e-learning) module, available through a web browser; an off-line module that is an e-book, or interactive DVD (iDVD), being easily carried by students; and the m-learning tool, with a competitive module and a reduced version of the e-learning contents.

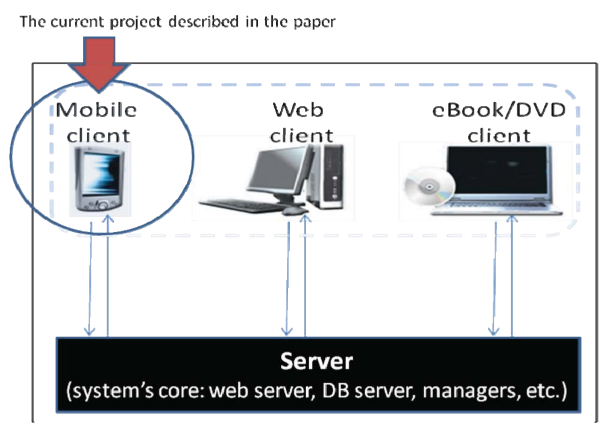

Figure 6. Client-server architecture of the framework.

The architecture for the competitive module includes four main sub-modules (Fig. 7). One of them is the manager of classifications and featured tournaments (CL). All the information is gathered from the central database of the system. Students login to a CL and games and submit results through their respective module, which also add the functionality of submitting new exercises to be played in a CL. The module related with teachers integrates all the functionalities necessary for the correct management of the competitions. One teacher can add new exercises, with the corresponding type descriptors, to the database and configure CL tournaments, which can be formative or for evaluation purposes. Through this sub-module, teachers access the Automated Evaluator (AE) sub-module, configuring it according to the class of students they have in mind to compete. This AE module crosses the submitted results (implemented programs) with the configuration made by teachers and the exercises descriptors taken from the database to evaluate how many goals were "scored" by students.

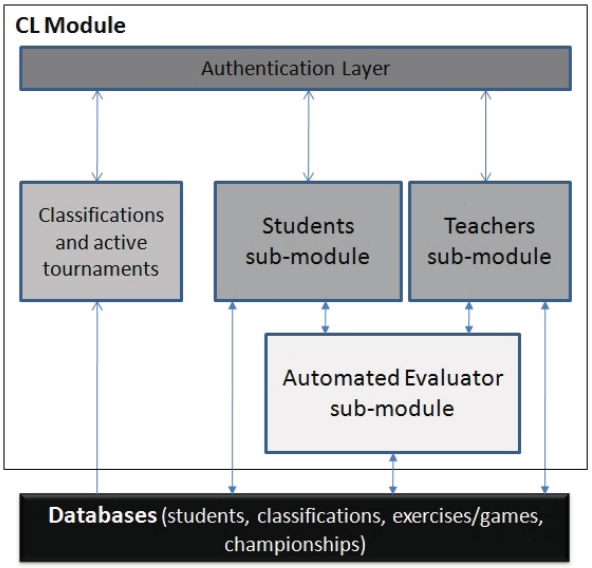

Figure 7: Architecture of the mobile device application.

C. *Development Issues of the Mobile Application*

The MoCoL client is a mobile application developed in Java (J2ME) for devices that support the MID profile. This application allows the user to interact with the central system and with teachers.

This client application is generic, in the sense that it is independent of the server-side applications. The application has some functions that are independent of the implemented prototype. It has two modules: one with functions to interact with the server via Bluetooth and another one to manage the possible information received from the system. Therefore, the client application uses the JSR-82 and the BlueCove APIs as the server application does.

Not all the mobile devices can run the first module to interact directly with the system. To accomplish that, the device must be embedded with the JSR-82 API. If a device does not embed the API, a possible solution is the implementation of a web server, making available an URL address to be accessed through the WAP browser of the mobile device. In this way, a student will be able to receive XML documents to consult later and to store them in the client repository, a Record Management System (RMS).

The module to manage the received information uses the kXML library in its implementation to make the parsing of the XML documents. kXML provides an XML pull parser and writer suitable for all Java platforms, including J2ME. Because of its small footprint size, it is especially suited for Java applications running on mobile devices.

VI. Conclusions and Future Work

The use of m-learning tools, if correctly conceptualized and built, constitutes an efficient complementary tool to the traditional teaching methods.

So, in this context, it was presented the development of a mobile learning framework for analog electronics course. The theoretical content of the course was structured in several interactive modules. At the end of each module, there are quizzes allowing students to be evaluated by themselves or by course teachers. The teacher receives automatic SMS from the student's mobile phone. This allows the teacher to have access to the student's progress and comments about the images and multimedia animations.

As future work, it is intended to study how to overcome some disadvantages found in m-learning, such as its high costs, the possibility for mobile devices to be misplaced or stolen and the difficulty to use mobile devices in noisy environments. Yet, another future step will be in the direction of creating the best interfaces to deal with the small screen size of the devices, the limited memory size, the small keyboards and limited battery life, among other issues.

Another important point for future work is the dissemination of the results of a questionnaire survey that is already being carried out among the students of the course.

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M2Learn: Towards a homogeneous vision of advanced mobile learning development

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***Abstract*—The vertiginous penetration and advance of mobile devices in all levels of our society leads towards new technological challenges. This paper is focused on the application of mobile devices in the learning environment, since the current mobile learning development is finding several problems and lacks, such as use of the new features (e.g. location and motion sensors) and the desigh without having including the existing e-learning services. This paper introduces a framework created as a need to interconnect the mobile learning environment with context aware systems and existing e-learning resources. The paper describes the requirements that a framework like this must support, to finally give an overview of the author's solution.**

Keywords-middleware; mobile learning; service-oriented learning; ubiquitous learning.

I. INTRODUCTION

Nowadays, mobile computing is one of the fastest growing areas within the technology industry worldwide. Rates of use of mobile devices in western countries are around 90%, having the youngest generations as main users [1]. One of the reasons of this success is the improvement in the devices' technical features and the low prices. New generations of mobile devices have wider and touchable screens, built-in digital cameras, and connectivity through Wi-Fi or 3G. In many cases it is even possible to find Global Positioning System (GPS) receivers, RFID, NFC readers or smartcards integrated.

All these new technologies inside a small and portable device are giving rise to a new generation of applications in all kind of environments. These are applications more aware of the user's context that enable connectivity and communication every time and everywhere. One of the environments where these devices can suppose an inflection point is education. Here, mobile computing acquires some specific features to support the enhancement of the learning process.

On the other hand, proliferation of mobile devices causes the increase of the demand of mobile learning development. As a result, it creates the need of some kind of software that could help in the development tasks. For that reason, many systems have been created to decrease the inherent complexity of the technologies implied in the mobile learning development.

This paper arises as a response to current research on mobile learning projects, which are geared mostly to implement the e-learning and traditional teaching methodologies on mobile devices. It means that many of the existing mobile learning applications are based on concepts such as study and assessment of digital material via mobile phones. Mobile devices are not the ideal technology to carry out these tasks due to the small size of its interface (display and keyboard).

The paper might be of interest for those involved in the development of mobile learning applications, since the introduced framework could become a powerful and useful tool for them; for those also designing supportive tools to simplify the development of mobile learning applications; and in general for those involved in the development of any kind of e-learning or m-learning application, since the paper introduces a service-oriented methodology for the development of applications.

The paper is structured as follows: Chapter II offers an overview of the main goals of the system. Chapter IV introduces the most relevant requirements to have in consideration to design a framework for supporting mobile context-aware applications. Chapter V relates the reasons why e-learning platforms and applications should not be left aside of mobile learning design. Chapter VI introduces the design of the proposed middleware. Chapter IX offers an overview of the evaluation to be carried out in the following months; and Chapter X some conclusions.

II. OBJECTIVES

Mobile devices are a very familiar tool for learners. Their experiences are closer to the use of videogames; watch videos; communication via mobile devices; and use of collaborative technologies (e.g. blogs, wikis, mash-ups and social networks) than to be a mere listener in a master class given by a teacher. Therefore, thanks to the use of these devices, students will take an active role in the learning process in a more interactive and according way to what they are accustomed to use. Learners will feel more motivated and engagement with learning. This idea was remarked by Elliot Soloway, an expert in mobile learning from the University of Michigan: "The kids these days are not digital kids. The digital kids were in the '90s. The kids today are mobile, and there's a difference. Digital is the old way of thinking, mobile is the new way."

M2Learn project is intended to give a step further in the state of the art of design of mobile learning applications. It supports the development of innovative mobile learning applications that really complement and enrich the learning experience. This is a learner-centred paradigm that really encourage the “anywhere, anytime”, improving the social interactions, providing a personalized educative experience to each learner, and reaching to places where traditional or on-line learning cannot reach. M2Learn Middleware is devoted to help mobile learning to find its place in education, as a complement to traditional and on-line learning instead of replace them and promoting blended approaches.

The main objective of the M2Learn project is to implement a middleware devoted to simplify the development of mobile learning applications based on the following characteristics:

- Middleware that simplifies the integration of:
  - Context-aware systems
  - Location-based technologies (GPS, RFID, Wi-Fi, ...)
  - E-learning resources (digital content, chat, forums, on-line labs, evaluation, ...)
- Offering collaboration capabilities (synchronous and synchronous communication; Web 2.0, ...)
- Open and flexible architecture with a service-based infrastructure (Through Web services and SOAP)

Through this development, educational organizations will achieve successful m-learning projects, because it encapsulates the inner complexity of the location techniques, learning services, context-awareness systems and management of e-learning resources.

III. Existing systems to support mobile learning development

Lately, many frameworks and middlewares have been created to decrease the complexity and simplify the design and development of mobile applications. Although few of them are devoted specially for mobile learning, we have focused our research in all the scope, i.e. learning-focused or general purpose. The reason is because any middleware for general mobile applications development can be also used for mobile learning purposes, although it will lack in some specific learning requirements, such as integration with e-learning platforms, protocols, applications and standards.

One of the first environments created to support ubiquitous computing is the Context Toolkit [2]. It is a context-aware framework developed at Georgia Institute of Technology. Its main strength is the use of Widgets to encapsulate the complexity of the lowest levels, as the sensor management. They also provide callbacks to notify applications of changes, and offer attributes that may be polled by applications [2].

Other related example is the SOCAM (Service-oriented Context-Aware Middleware) project [3], which uses a central server (context interpreter) and several context providers. The central server retrieves context data from the context providers, which have previously processed it. At the top level layer are the context-aware applications in the mobile device that make use of the context data provided by the central server.

A similar architecture is introduced in the CASS project (Context-awareness sub-structure) by Fahy and Clarke in [4]. This architecture is not designed for mobile devices with sensors embedded, but for context-aware environments with spread sensors that communicate with a mobile device.

A different approach is developed by Hansen in [5] within the HyCon Framework, which is devoted mainly to hypermedia services, although it also supports J2ME applications. The architectural design is similar to other hypermedia architectures, such as the Dexter architecture [6], the Open Hypermedia System Working Group’s Open Hypermedia Model [7] and Construct [8]. The difference is the sensor layer that encapsulates the sensing management. Other interesting feature of this framework is the integration of external services, such as a Weather Server and a Location Mapper, which use the information retrieved from sensors (Context Interpreter) to obtain a more sophisticated one.

Within the MOBIlearn project is developed the Open Mobile Access Abstract Framework (OMAF) [9] based on layers of infrastructure and application profiles. It is interesting from a design point of view because it is based on the IMS Abstract Framework.

IV. Technical Requirements involved in Development of Mobile Learning Applications

A. Architectures for Development of Mobile Learning Applications

This section describes the most common architectures used in the existing middlewares for the development of mobile applications. The objective is to establish the basis for the posterior definition of the M2Learn architecture.

According with Biegel, the main features that a programming model to develop mobile context-aware applications must address are [10]:

- Capture of context data
- Uncertainty of context data
- Representation of context data
- Privacy
- Scalability
- Synchrony
- Extensibility and reusability
- Centralized/Distributed resources

In relation with the first featured cited by Biegel, there are different approaches to acquire contextual information according with the work of Chen [11]:

- **Direct sensor access.** Used in devices with embedded sensors. The application gathers the desired information directly from these sensors. In this approach there is no additional layer in charge of retrieving or processing sensor data.
- **Drivers for the sensors are hardwired into the application**. This tightly coupled method is usable

only in rare cases and not suitable for mobile applications.

- **Middleware infrastructure**. Modern software design uses methods of encapsulation to separate the different layers involved in the design. The middleware-based approach introduces a layered architecture with the intention of hiding low-level sensing details. Compared to direct sensor access this technique simplifies extensibility and promotes reusability [12].

Other fundamental factor in the architecture design is the use of centralized or distributed resources. If the system is autonomous and does not require any connection with other systems, the architecture is considerably simplified. On the other hand, the distributed approach must affront the communication challenge, which can be carried out using different techniques [13]:

- **Widgets**. A widget is a component that offers a public interface for a hardware sensor [14]. Widgets hide low-level details of sensing and simplify application development due to their reusability. Thanks to the encapsulation in widgets it is possible to exchange widgets that provide the same kind of context data
- **Networked services.** This approach is based on a more distributed architecture. It requires a service discovery server that will manage the services offered in the network [15].
- **Blackboard model**. The blackboard model is an asymmetric approach that requires a server where the clients are subscribed to be notified when some specific event occurs. In this system, there are some components (e.g. sensors) that provide information to the blackboard. This information is used by other components to provide more information. When the existing information in the blackboard matches with the needs of some client (higher level components), it is notified.

The most common design approach for distributed context-aware frameworks is a classical hierarchical infrastructure with one or many centralized components using a layered architecture. This approach is useful to overcome memory and processor constraints of small mobile devices but provides one single point of failure and thereby lacks robustness.

And finally, the last relevant feature regarding to architectural design is the way to represent the contextual information. According to Stephanidis in [15] it can be structured as follows:

- key-value model
- markup scheme model
- graphical model
- object-oriented model
- logic-based model
- ontology-based model

This last one is considered the most promising for context-aware systems, due to the fact it offers reasoning features. However, for mobile systems the object-oriented model can be more effective and flexible as the Hydrogen project demonstrates in [16]. That is because some of them are able to manage their own context data without connecting with an external central server. Object-oriented models are usually supported by middleware architectures providing distributed context handling. Whilst ontology-based models usually make use of centralized context management components [15].

B. Interoperability through the service-oriented paradigm

Nowadays, technological interoperability is a fundamental component within complex systems, because of the need of interconnection among different environments and systems. It takes special relevance in the mobile field, due to the fact there are different kind of devices, with different Operating Systems and hardware features. Thus, usually new systems developed for these devices are not isolated programs, but they must connect to other services and resources to retrieve and send information. This connection is one of the key issues within the mobile computing paradigm.

According to the literacy there are no defined standards for interoperability in mobile learning that specify e.g. the interface between a mobile learning application and a LMS or a location service.

On the other hand, there are specifications, such as the "IMS Abstract Framework: Applications, Services & Components" (IAF), which is a mechanism to define the set of interfaces for which interoperability specifications will be needed by some application domain [17]. This specification can be followed as a guide for development of mobile learning frameworks. It offers a structured architecture that allows interoperability between different components, using mainly SOAP. It can be used specially in the interconnection with external services, e.g. services from a LMS, contextual services, etc.

The main principles of this framework [17] are:

- Interoperability – the specifications are focused on the exchange of information between systems.
- Service-oriented – the exchange between the systems is defined in terms of the services being supplied by the collaboration of the systems.
- Component-based – the set of services will be supplied as a 'sea of components' that can be mixed and matched to form a particular service.
- Layering – the total set of services required to make an eLearning system will be modeled as a set of layers.
- Behaviors and Data Models – a service will be defined in terms of its behaviors and data model, and can be supported through multiple bindings e.g. Java, XML, web services, etc.

IAF is a layered model, consisting of four layers [18] as it is shown in figure 1:

- Application layer.
- Application Services layer.
- Common Services layer – a set of services that are available to the application services.
- Infrastructure layer – this provides the end-to-end transaction and communications services for the application and common services.

The interface between layers is the Service Access Point (SAP), which is provided by the services. It means that each service will offer one or more SAPs, which will be the communication interface with other layers. This concept can be implemented for example through an API.

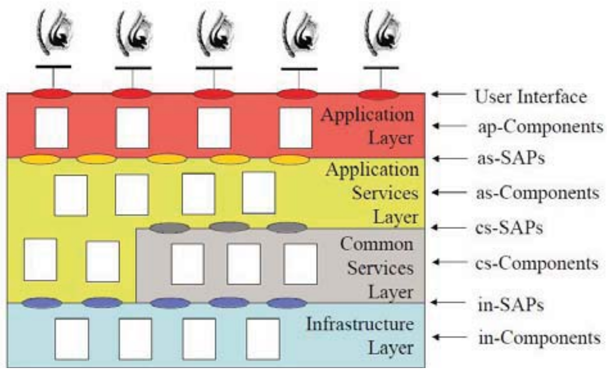

Figure 1. IAF Layers [17] includes, from bottom to top, the following layers: Infrastructure, Common Services, Application Services and Application.

V. ENABLING INNOVATIONS ON MOBILE AND UBIQUITOUS LEARNING

According with several authors, such as Shuiler [18], the successful implantation of mobile learning applications within the educational environment involves some changes in the mentality of both technicians and trainers. In first place, the development of new pedagogy theories that fulfil the mobility opportunities that new technologies are offering.

Secondly, the design and implantation of innovative learning applications that provide an added-value to the educational experience, complementing both traditional and electronic learning. Third, the support to fill the gaps between differentiated access and technologies. A wide range of technologies and their inner complexity are a challenge to overcome by teachers and learners. And finally, move these new innovations into the real educational environment by training teachers.

As a result, authors have developed a system to support the development of these innovative mobile learning applications within the new learning approaches. The M2Learn project arises as a response to current research on mobile learning development, which is usually geared to implement the same methodology used in the e-learning and traditional teaching on mobile devices. It means that many of the existing mobile learning applications are based on concepts such as study and assessment of digital material via cell phones. Mobile devices are not the ideal technology to carry out these tasks due to the small size of its interfaces (display and keyboard).

Therefore, new trends must exploit the potential offered by these devices changing the methodology and thinking on new scenarios. There, new mobility features must offer a complement to traditional education, as for example:

- Learning outside the classroom (botanical garden, archaeology, etc.);
- Learning on the move (transportation, running, etc.);
- Informal and lifelong learning (museums, aircraft, zoos, etc.);
- Collaborative learning (performance review in class, voting, resolving queries, etc.).

The other focus of the project is the fact that most mobile learning applications have left behind what has been established as the main repository of learning resources during the last years: the e-learning platforms, e.g. Web-CT, dotLRN, Moodle or Sakai.

Lately, much effort has been undertaken to develop e-learning platforms able to offer the services and resources that students need within the learning process. But most of these new mobile applications leave them aside, created ad-hoc, with almost none interoperability with other systems.

Finally, reviewing the technical literature related to the mobile learning field, we find that there are no tools to facilitate the development of mobile applications that comply with the new paradigm of mobility: integration of resources and services from e-learning platforms with context-aware systems and collaborative environments.

VI. M2LEARN: A SERVICE-ORIENTED MIDDLEWARE FOR THE DEVELOPMENT OF MOBILE AND UBIQUITOUS LEARNING APPLICATIONS

Achievement of a successful implantation of mobile devices in education requires the development of applications able to provide the needed support to the mobile learning experience. Thus, authors have committed to create a middleware devoted to support the development of new generation mobile learning applications.

Based on the analyzed features, the following technical requirements are part of the final design:

- Context-awareness through location technologies, e.g. GPS, Wi-Fi, RFID, etc.
- Internal context representation using an object-oriented model.
- Capture of contextual information through a middleware infrastructure. It hides low-level sensing details to higher level layers.
- Communication between components (both internal and external) through the use of Widgets and Web Services using SAPs (IAF based). Together with the middleware infrastructure it provides reusability and simplifies the application development.

These factors are common for the development of any kind of mobile application. However, focusing on mobile learning, other key factors have been kept in mind in the design are:

- Integration with existing e-learning resources
- Support for social collaboration

The reason is that e-learning platforms are currently the centre of the on-line and blended education. These platforms are a repository of both content and services. That is why mobile applications should not be designed independently of the already developed e-learning standards and platforms, without taking advantage of all the existing resources. Within the mobile environment, existing e-learning resources can be very useful to better personalize the services provided to learners. For example, using the credentials (login and password) it is possible to retrieve information about learner's educational environment such as student's degree or subjects. This information will be provided to higher level applications to personalize the services offered to the student. In fact, there is a lot of contextual information about the learner that can be used to improve the learning experience: for example, personalized information services or search results in the library.

M2Learn middleware interacts with the university LMS through a set of Web Services, providing an interface to implement some functionalities in a mobile device, e.g. access to forum rooms, content or FAQs. In addition, there are other advantages related to the re-use of services instead of creating them again: authentication, tracking activities, evaluation, content, etc. LMSs can provide also very useful contextual information. On the other hand, social interaction and collaboration is one of the key issues for modern learning. It has been widely implanted in the e-learning environment and must be moved into the mobile one.

M2Learn project offers several additional advantages that mean an advance in the state of the art of mobile learning development:

- Interrelation between hitherto isolated location technologies (e.g. GPS, RFID, Wi-Fi, etc).
- Interoperability between existing services in e-learning platforms and mobile devices.
- Encapsulation and homogenization of student's contextual information (based on geo-location technologies and other profile data).
- Encapsulation and standardization of services, such as those from e-learning platforms, which provide an added value to the mobile application, e.g. intelligent auto-response, information services, etc.
- Reduction in development time.

This middleware manages several location sensors to provide contextual information about the user. For that reason several sensor controllers (Widgets) have been developed to understand the information provided by sensors (Figure 2).

The system has been designed using open interfaces in order to make easy to add other services (e.g. new location methods such as cell towers or Bluetooth [19]).

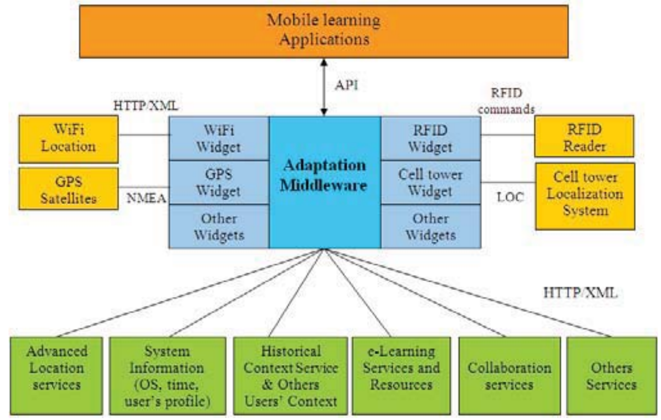

Figure 2. M2Learn Architecture includes location technologiesWidgets to manage e.g. Wi-Fi, GPS or RFID. The Adaptation Middleware integrates several services, some of them from e-learning platforms.

Adaptation layer processes the contextual information provided by widgets to access to other services, e.g. information in a LMS, e-mail, etc [20], to get more contextual information. This is the most important layer in the architecture because offers an interface to top level applications. Mobile applications will not have to interact with sensors or services, and even they will not know from which sensor or service the information comes from. This interface provides all the contextual information and educational services in a transparent way, ensuring the applications will not have to worry about the implementation of lower layers [21].

This architecture considerably simplifies the development of mobile learning applications. For example, users will be able to create a mash-up system using the location information instead of learning how the NMEA protocol of the GPS works; or communicating through a serial port with an RFID controller to read the information from an RFID tag, without understanding the RFID commands or the data organization inside the tag. Or they will create a mobile blog using the services provided by an e-learning platform, but they will not need to create any web service in the language of the platform or understand how its database is structured. They just use the simple interface with information and services provided by the M2Learn Middleware.

At this stage, most of the M2Learn framework has been already developed, although evaluation has not been carried out yet.

VII. Evaluation

Evaluation will be conducted through a pilot using students of a "Professional Expert Course on Mobile Programming". They will develop several applications using the framework. Later, students will complete a questionnaire on user satisfaction and the simplification degree obtained through the framework's use. Evaluation will also include other instruments such as interviews, and development time required.

VIII. CONCLUSIONS

M2Learn project gives a solution to the development problems within the mobile learning field. At the same time, this project promotes the creation of innovative applications and provides the guide for the development of new applications based on the new key factors of mobility in learning: context-awareness, social interaction and integration of e-learning resources.

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Adaptive Ecology M-learning for National Park Based on Scaffolding Theory

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***Abstract*—An adaptive ecology m-learning framework applied for national parks is proposed in this paper. The traditional ecology guiding service uses static web page or fixed placard to prompt and provide ecology information to learners. It can not provide adaptive learning anytime and anywhere. Learners can not obtain real-time ecology guiding information and have a good adaptive learning based on learners' knowledge background, and time and location. This study proposes a framework based on Scaffolding Theory that provide learners mobile, dynamic and adaptive ecology guiding service to national parks. Scaffolding Theory is to support learners a knowledge structure for systematic learning. Based on Scaffolding Theory, learners are identified by background (e.g. age and gender), knowledge (e.g. cognitive base, knowledge requirement and learning objective), and interests. Moreover, adaptive and appropriate ecology knowledge based on learners' properties is provided dynamically. Furthermore, learning steps and contents are able to be adjusted flexibly by learners' feedback. In addition, this study also adopt context awareness to provide the learner a suitable route planning for ecology guiding service according to environment factors such as weather condition, time and season, prediction of tide, UV rays and rain rate where learners located. Landscapes and ecology events such as Migratory birds in transit within the route can be actively delivered to learners immediately using interactive applications such as multimedia messages (e.g. text, image and video). Attention and enjoyment of learners can be increased and ecology education purpose of national parks can be achieved.**

Keywords: Context-aware computing, m-learning, Scaffolding Theory

I. INTRODUCTION

A "national park" is an area with a country's special features or cultural or historic significance. The first national park in the world was Yellowstone National Park, established in the US in 1872 and, since then, over 3,800 national parks have been established worldwide [1]. International Union for Conservation of Nature, IUCN, founded in 1948 as the world's first global environmental organization, today is the largest professional global conservation network and a leading authority on the environment and sustainable development. IUCN's mission is to help the world to find pragmatic solutions to our most pressing environment and development challenges [2]. The management of national park gradually escapes the way of "no people in national park" and hopes to find a harmony way between human and wild life. By sustainable interpretation and the ecology tourism with profound experience and respect to nature, visitors can observe and learn from nature and then the sustainable management of national park can be achieved [3-7]. Therefore, ecology education is an important function of national park management. Figuring out how to achieve the purpose of guiding service of national park through new technology assistant and then let more people enjoying, understanding and acting to improve, the natural environment, more often is the intention of this study.

Traditional ecology guiding service of national park has its limitations. For examples, static web guideline and restricted interaction interface. In such ecology guiding service can not provide the learners with adaptive learning. The learner does not gather enough ecology information from the traditional ecology guiding service. If the learner desires more ecology information to help them to find out more interests about the national park, they have to discover by themselves, or ask local ecology interpreter for more information. However, it is difficult to preserve the learner's learning experiences and pass down the oral interpretation.

In this study, the Scaffolding Theory and knowledge creation procedure are proposed to provide an adaptive ecology learning approach for the learners. Meanwhile, new wireless telecommunication technologies and interactive applications are used to construct a framework of adaptive ecology m-learning. In this framework, the learner can obtain ecology route planning and adaptive m-learning according to their inherent properties and extrinsic environmental factors as well as on-line interact with the interpreters by multimedia messages. These precious multimedia messages can be preserved and passed down, and then carry out efficient utilization of ecology information.

II. LITERATURE REVIEW

A. Functions of National Park

Taiwan, Formosa, a little island straddling the Tropic of Cancer, was known for hundreds of years as Formosa. Taiwan covers an area of 36,000 square kilometers, which is 0.025% of the total area on earth. Taiwan has undergone dramatic mountain building periods, interference by ice age, and is thus miraculously endowed with diverse ecosystems that range from the tropical to alpine. Taiwan has a diversified natural environment that includes high mountains and sea waters. Its unique and varied topography and ecosystems give rise to a multitude of compelling and captivating images. The movement for national parks and nature conservation in Taiwan began in 1961 and has since led to the establishment of seven national parks on the island from 1984, including Kenting, Yushan, Yangmingshan, Taroko, Sheipa, Kinmen and Dongsha Marine National Parks. Each national park owns it's unique characteristics and educational indicators. For instance, Kenting National Park, locates at the southern tip of Taiwan, possesses diversified terrain and tropical climate, and breeds rich and fertile vegetation ranging from upland to coast with a full variety of living species [8].

The aim of national parks in Taiwan is to maintain the unique natural environment and biodiversity within the parks through effective operation, management and conservation. Thus national parks should maintain three goals: preservation; education and recreation; and research[9]. In terms of characteristics and management methods, national parks have four functions: 1.To protect the natural environment , 2.To preserve species and native genetics, 3.To furnish national recreation and support the local economy, 4.To promote academic research and environmental education [8].The fourth function highlight that National parks are rich in ecology resources and through offering resources for scientific research and environmental education, they can contribute to people's understanding of the natural and cultural assets of the country. Therefore, national parks are not only providing functionality of travel and leisure, but also playing an important role of environment and ecology education. Thus, National parks should provide educational and recreational activities to develop public awareness of the beauty of nature and establish environmental values.

To sustainably conserve natural resources, national parks shall provide recreational activities such as eco- tourism to minimize environment impact. This could make from interpretation service, a method of national park management, and its role of communication between park administration, park resources and visitors is shown in Figure 1. Through interpretation, visitors can understand the goals of park resources management and obtain a joyful and safe tourism experience of national park. Also, it can create a knowledge-based recreation experience, reduce the visitors' activity impact on environment and improve the visitors understanding to park recreation. The interpretation service in national parks plays an important role in the overall quality of the parks. It can assist in explaining services provided by the parks, the eco-system of the area and management regulations emanating from the national parks' headquarters [10]. Therefore the purpose of interpretation is promoting environmental education and environmental awareness through appreciation, understanding and the new experience. Interpreters can purposefully make influence in how audiences think, feel and behave with respect to things they interpret.

The Food and Agriculture Organization of the United Nations (FAO) divide interpretation resources to three categories: geological feature, biological feature and human history. U.S. National Park Service defines interpretation resources to six categories: landforms of the present, geological history, land communities of plants and animals, aquatic ecosystems, historic and archeological themes, and works of humans. For instance, Kenting National Park, the site of Taiwan's first national park, is a popular tourist destination for locals and foreigners alike. Due to its geographical location, it has a tropical climate, which has resulted in rich natural resources and scenic landscapes, as well as a unique cultural style. It's interpretation resources include not only the six categories as mentioned, but also special sky landscape, such as "mountain winds" [11]. Therefore, it's important to provide efficient and suitable self-guiding interpretation information to different visitors in order to lead visitors into profound experience of Kenting's unique resources. How can interpretation really make a difference? This paper introduce some mechanisms, such as scaffolding and context awareness, try to illustrate a adaptive system that fit visitors various characteristic, diverse park resources and real-time environment changes in order to provide an optimized interpretation service.

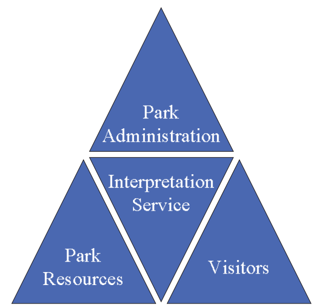

Figure 1 Relation between park administration, park resources, visitors and interpretation service

B. Scaffolding Theory

Scaffolding Theory was first introduced in the late 1950s by Jerome Bruner, used the term to describe young children's oral language acquisition and helped by their parents when they first start learning to speak, young children are provided with instinctive structures to learn a language. Wood, Bruner, and Ross' (1976) idea of scaffolding also parallels Vygotsky's work [12]. The term "scaffolding" was developed as a metaphor to describe the type of assistance offered by a teacher or peer to support learning. In the process of scaffolding, the teacher helps learner master a task or concept that learner is initially unable to grasp independently. The teacher offers assistance with only those skills that are beyond the learner's capability. The most significance is to allow the learner to complete as much of the task as possible, unassisted. The teacher only attempts to help learner with tasks that are just beyond his current capability. Learner errors are expected, but, with teacher feedback and prompting, learner is able to achieve the task or goal. When learner takes responsibility for or masters the task, the teacher begins the process of "fading", or the gradual removal of the scaffolding, which allows learner to work independently.

Scaffolding Theory proposes that teachers will act as assisting roles in the learning process to provide a temporary support (scaffold) in order to assist learners to construct self learning. Scaffolding Theory includes two main procedures, which are to setup the scaffold and phased removal of scaffold. The scaffold can be a teaching strategy or a teaching tool; it can be provision of clues, a reminder, encouragement, solution, providing an example or assistance through information technology. Meanwhile the learning responsibility is gradually shifted from teachers to learners and eventually learners can lead their learning [13]. That is to say, learners can construct knowledge of their own and develop themselves to be independent learners. Hwang, Lee and Chen's study [10] uses the interpretation service of five National Parks in Taiwan as an empirical study to create a relationship model for tourists' involvement, interpretation service quality and place attachment. Their results show tourists' involvement has a positive significant effect on perceived interpretation service quality, as does place attachment. Also, there is an indirect positive significant effect from place attachment to interpretation satisfaction. Therefore, self-learning with scaffold support is a feasible method to improve the satisfaction and knowledge transfer of interpretation of national park.

C. Adaptive Knowledge

In human-computer interaction, user interface events and frequencies can be recorded and organized into episodes. By computing episode frequencies and implication relations, we can automatically derive application-specific episode associations and therefore enable an application interface to adaptively provide just-in-time assistance to a user. Liu, Wong and Hui (2003) identify five issues related to designing an adaptive user interface: interaction tracking, episodes identification, user pattern recognition, user intention prediction, and user profile update. To adapt to different users' needs, the interface can personalize its assistance by learning user profiles or properties. For example, by detecting and analyzing users' behavior patterns in using Microsoft Word, the interface can automatically assist users in several Word tasks [14]. Personalized support for learners becomes even more important, when e-learning takes place in open and dynamic learning and information networks. Dolog, Henze, Nejdl and Sintek [15] proposed a service-based architecture for establishing personalized adaptive e-Learning systems with well-established personalization functionality, and open, dynamic learning repository networks, where personalization functionality is provided by various web-services. Computer can act as the supporter of knowledge construction by providing customized learning content which learners can Restructuring and construct to new knowledge and meaningful learning. Computer assist learning combined with integrated hypermedia interface can reveal information in nonlinear way and learners can reading the materials in their favorite order instead of in proper sequence. However, hypermedia system didn't present knowledge content in efficient linkage and ignore the relationships of knowledge. Some Web sites are intricate but not intelligent enough; while Web navigation is dynamic and idiosyncratic, all too often Web sites are fossils cast in HTML. Researches indicated the negative of traditional e-learning, such as : 1. Beginners lost the learning direction which cause the learning frustration , 2. Aimless browsing which cannot be construct to a comprehensive knowledge structure, 3. Overloading of information, 4. Weak relationship of information and hard to integrate the knowledge conception, etc [15-18]. Learners can not construct their own knowledge bases by making meaningful connections among the ideas as they perceive.

Therefore, adaptive web-based systems attempt to fight the "one size fits all" approach to e-learning. Farrell , Liburd and Thomas [19] describes one solution to the problem of how to select sequence, and link Web resources into a coherent, focused organization for instruction that addresses a user's immediate and focused learning need. Their Custom Course System consists of a Search Engine, the Dynamic Assembly Engine, and Course Player. A system is described that automatically generates individualized learning paths from a repository of XML Web resources. Each Web resource has an XML Learning Object Metadata (LOM) description consisting of General, Educational, and Classification metadata. Dynamic assembly of these learning objects is based on the relative match of the learning object content and metadata to the learner's needs, preferences, context, and constraints. Learning objects are connected into coherent paths based on their LOM topic classifications and the proximity of these topics in a Resource Description Framework (RDF) graph [19]. Brusilovsky [20] reviewed the adaptive functions, such as: 1.Adaptive textbooks created with such systems as InterBook, NetCoach or ActiveMath can help students learn faster and better, 2. Adaptive quizzes developed with SIETTE evaluate student knowledge more precisely with fewer questions, 3. Intelligent solution analyzers can diagnose solutions of educational exercises and help the student to resolve problems, 4. Adaptive class monitoring systems give the teachers a much better chance to notice when students are lagging behind, 5. Adaptive collaboration support systems can enhance the power of collaborative learning. He therefore presents an architecture for adaptive e-learning based on distributed reusable intelligent learning activities [20].

When interpreters present strongly relevant themes, their audiences are provoked to think in theme-related ways. Theme-related thinking impacts beliefs about the interpreter's topic, which, in turn, can impact attitudes and ways of behaving that are consistent with those beliefs [21]. The potential benefits include improved visitor management, local economic and environmental gains and fuller community involvement. However, there are several pitfalls of linking interpretation and sustainable tourism should be considered; those are the dangers of over-interpretation, intrusion, creating 'quaint' tourist landscapes, and those of elitism [22]. Therefore, the adaptive knowledge mechanism in this study is to provide learners adaptive guiding materials (subjects and levels) real-time according to the context (learner and environment) and the previous feedback records. Those adaptive materials include: 1. Personalized knowledge concept structure, 2. Relative linkage and resources, 3. Multimedia and virtual reality materials, 4. Dynamic and expandable nonlinear leaning support, 5. Interpreter's guiding and other learners' collaboration. Learners and interpreters can form a learning scaffold and add knowledge to empty grid of their knowledge scaffold by Play Jigsaw and Fill-in-the-Structure, and then complete their knowledge concept map. The adaptive knowledge mechanism based on Scaffolding can provide visitors suitable dynamic guiding materials according to their needs and interests in order to enhance their attitude to nature and self-learning.

D. Contex- Aware Computing

Context is an implicit situation information. For example, in the natural environment, weather is one of implicit situation information of context. The weather information of context is such as temperature, humidity and rain rate. If the information of context can be aware of change and treated with computing techniques, it should be to make interacting with computers easier. For example, if the sensor of air conditioner is aware of indoor temperature rising, the processor should inform the compressor to speed up the operation and release more cool air to lower the indoor temperature. Therefore, understanding how context can be used will enable designers to choose what context to be used in their applications, and help designers to determine what context-aware behaviors to be supported in their applications.

Most people tacitly understand what context is, but they find that it is hard to illustrate clearly. Brown *et al*. [23] define context as location, identities of the people around the user, the time of day, season, temperature, etc. Anind and Gregory [24] define context as: *Context is any information that can be used to characterize the situation of an entity. An entity is a person, place or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves*. This definition makes context-aware easier for an application designer to enumerate the context for a given application scenario. If a part of information of context-aware is used to characterize the situation of a participant in an interaction, then that information is context. For example, if the learner's location can be used to characterize the learner's situation, then the learner's location is context.

Schilit *et al*. [25] claim that the important aspects of context are: where you are, who you are with, and what resources are nearby. They define context to be the constantly changing execution environment. They include the following pieces of the environment:

- *Computing environment* available processors, devices accessible for user input and display, network capacity, connectivity, and costs of computing.
- *User environment* location, collection of nearby people, and social situation.
- *Physical environment* lighting and noise level.

A categorization of context types will help application designers to find out the pieces of context that will be useful in their application. There are certain types of context are: location, identity, activity and time[24]. The location is meaning that the learners' physical position presented by longitude and latitude. The identity represents the learner's properties such as age, gender, attitude, preference, knowledge-based and learning period. The activity includes an environment where the learner located, and events what occurrences happened in that environment. The time is the local time where the learner located.

Context-aware computing was first discussed by Schilit and Theimer [26] in 1994. Context-aware computing is similar to an application that "adapts according to its location of use, the collection of nearby people and objects, as well as changes to those objects over time". The first definition of context-aware application also given by Schilit and Theimer [26] restricted the definition from applications that are simply informed about context to applications that adapt themselves to context. Hull *et al*. [27] and Pascoe *et al*. [28-30] define context-aware computing to be the ability of computing devices to detect and sense, interpret and respond to aspects of a user's local environment and the computing devices themselves. Dey *et al*. [31] begin to introduce the notion of adaptation by defining context-awareness to be worked leading to the automation of an application system based on knowledge of the learner's context. Ryan [32] defines context-aware application to be applications that monitor input from environmental sensors and allow users to select from a range of physical and logical contexts according to their current interests or activities. Brown [33] defines context-aware applications as applications that automatically provide information and/or take actions according to the learner's present context as detected by sensors. Anind and Gregory [24] define context-aware as: *A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task*. This definition is more specific adapting to context and requiring that an application's behavior be modified for it to be considered context-aware.

E. Interactive Applications

In computer science, the term of interactive is referred to an application or software which receives and responses the input from humans. For example, the learner inputs multimedia messages or commands to an interactive application, then an interactive application makes an adaptive response to the learner. The interactive application, such as Web 2.0, has already been a trend of next generation application interface. The term of Web 2.0 is commonly associated with web applications which facilitate interactive information sharing, interoperability, user-centered design and collaboration on the World Wide Web [34].

The term of "Web 2.0" was created by Darcy DiNucci in 1999. In her article "Fragmented Future[35]", she writes:

> *The Web we know now, which loads into a window on our computer screens in essentially static screenfuls, is an embryo of the Web as we will know it in not so many years.*
>
> *The first glimmerings of Web 2.0 are now beginning to appear, and we can start to see just how that embryo might develop. The first stages of mitosis have begun, and the cells of the organism have begun to differentiate. Now we can see that the defining thing about the Web won't be any visible characteristic at all. The Web will be identified only by its underlying DNA structure—TCP/IP (the protocol that controls how files are transported across the Internet), HTTP (the protocol that rules the communication between computers on the Web), and*

URLs (a method for identifying files). As those technologies define its workings, the Web's outward form—the hardware and software we use to view it—will multiply. On the front end, the Web will fragment into countless permutations with different looks, behaviors, uses, and hardware hosts. The Web will be understood, not as screenfuls of text and graphics but as a transport mechanism, the ether through which interactivity happens. It will still appear on your computer screen, transformed by the video and other dynamic media made possible by the speedy connection technologies now coming down the pike. It will also appear, in different guises, on your TV set (interactive content woven seamlessly into programming and commercials), your car dashboard (maps, yellow pages, and other traveler info), your cell phone (news, stock quotes, flight info), hand-held game machines (linking players with competitors over the Net), maybe even your microwave oven (automatically finding cooking times for the latest products).

Web 2.0 is the network as platform, spanning all connected devices; Web 2.0 applications are those that make the most of the intrinsic advantages of that platform: delivering software as a continually-updated service that gets better the more people use it, consuming and remixing data from multiple sources, including individual users, while providing their own data and services in a form that allows remixing by others, creating network effects through an "architecture of participation," and going beyond the page metaphor of Web 1.0 to deliver rich user experiences [36].

F. Wireless telecommunication Technologies

The evolution of communication technology has been migrated gradually from wired to wireless, from narrowband to broadband, and from desktop to handheld. Digital information and multimedia can be obtained anytime and anywhere with available portable devices. The portable devices are such as Personal Digital Assistant (PDA), laptop, smart phone and netbook. These devices may surf internet using different wireless communication technologies. Several wireless telecommunication technologies are popular in the worldwide, such as HSPA (High-Speed Packet Access) and WiMAX (Worldwide interoperability for Microwave Access). HSPA includes two technologies: High-Speed Download Packet Access (HSDPA) and High-Speed Uplink Packet Access. HSPA is developed by 3GPP (Third Generation Partnership Project). It extends and improves existing WCDMA performance in packet data transmission rate. An advanced standard, Evolved HSPA, all called HSPA+, is soon to be release. HSPA increases packet data rates up to 14.4Mbps in the downlink and 5.8Mbps in the uplink, while HSPA+ further improves the performance of packet data rates up to 42Mbps in the downlink and 11Mbps in the uplink. The other popular wireless telecommunication technology is WiMAX based on IEEE 802.16 standard. It includes two main standards: 802.16-2004 is also called 802.16d referred to as "fixed WiMAX" and 802.16-2005 is also called 802.16e referred to as "mobile WiMAX". WiMAX is an OFDM-based physical layer providing packet data rates up to 144Mbps in the downlink and 35Mbps in the uplink. Both HSPA and WiMAX can provide broadband transmission to satisfy the bandwidth requirement of multimedia.

III. Framework

In this study, a framework of adaptive ecology m-learning for national park is proposed. This framework is also based on Scaffolding Theory to provide an adaptive m-learning for learners.

A. Framework

In Figure 2, the learners can use laptop, netbook, PDA or any available devices which support wireless telecommunication technologies such as HSAP or WiMAX. These devices assist the learner to access to operators' base stations which provide radio signaling and connect to internet. Once the learners connect to internet, they can obtain adaptive content of ecology guiding information and interact with the interpreters via the scaffolding ecology m-learning system. The adaptive learning application server generates adaptive content according to the learner's inherent properties and extrinsic environment factors. In Figure 3 illustrates the learner's inherent properties consisting of age, gender, preference, knowledge-based and attitude, and the extrinsic environment factors consisting of location, time, weather, season and event. The learner's learning period means how much time the learner would like to spend on ecology learning. The learner can learn the ecology knowledge independently with the scaffolding ecology m-learning system, or learn the ecology knowledge collaboratively with other learners and interpreters through the scaffolding ecology m-learning system.

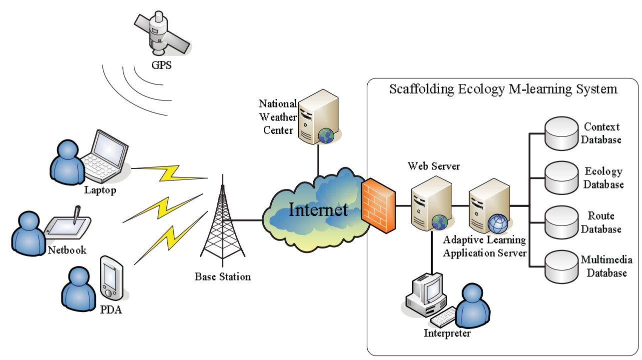

Figure 2 Framework

In this framework, four databases are deployed within the scaffolding ecology m-learning system. The Entity-Relationship Diagram (ERD) is shown in Figure 4. The context database stores the learner's inherent properties. The adaptive learning application server generates adaptive route plans based on context database and weather information retrieved from national weather center. The learner selects one of route plans, or asks the on-line interpreter to obtain a route plan depending on his/her interests. The ecology database stores related ecology information such as coastal and upland vegetations, animals, insects and marine creatures, etc. It can provide abundant resources of national park for the learners, or provide adaptive content for the learners based on their locations. The route database stores various paths for ecology guiding, travel and leisure. The route planning is based on the learner's properties and present environment factors to provide a suitable route planning for the learners. The multimedia database stores interactive messages such as text, audio, video and image from the learners or interpreters. For example, the learner records a piece of insect video, but he/she does not know what the insect is. He/She can upload the captured video to the multimedia database through the Web Server with Web 2.0 interactive application, and ask on-line interpreter about his/her question about unknown insect. The on-line interpreter searches the ecology database and responses the answer to the learner by multimedia messages. Therefore, in this framework not only provides adaptive content and suitable route planning, but also implement an interactive application between the learners and the interpreters.

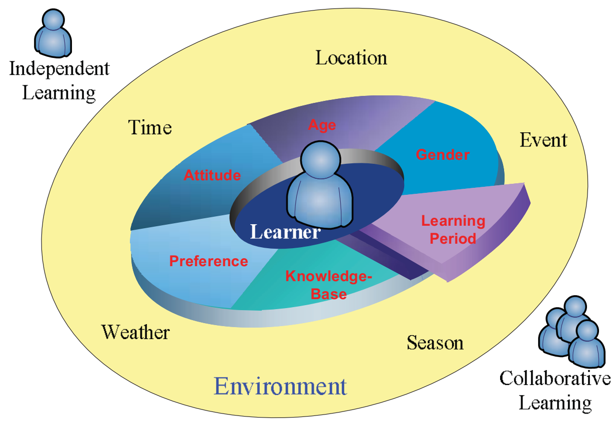

Figure 3 Learning context

The multimedia messages between the learners and the interpreters can be stored in multimedia database. These messages possess precious knowledge and experiences, and should be preserved. For example, if the learner records a piece of precious insect video, he/she can upload this video to the multimedia database through interactive application and share to other learners. Moreover, these messages can be preserved, shared and passed down through this framework.

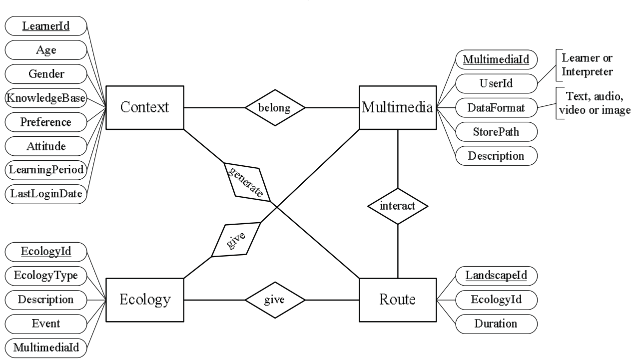

Figure 4 Entity-Relationship Diagram

B. *A Scaffolding m-learning model with Knowledge Creation process*

In Figure 5 illustrates that through "context check", "adaptive materials" and "knowledge construction" mechanisms based on Scaffolding Theory, learners can achieve self-guided leaning.

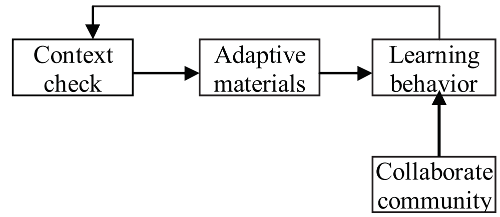

Figure 5 scaffolding m-learning model

Hogan and Pressley (1997) summarized the literature to identify eight essential elements of scaffold instruction that teachers can use as general guidelines as followings. Note that these elements don't have to occur in the sequence listed.

- Pre-engagement with the student (learner) and the curriculum
- Establish a shared goal
- Actively diagnose student needs and understandings
- Provide tailored assistance
- Maintain pursuit of the goal
- Give feedback
- Control for frustration and risk
- Assist internalization, independence, and generalization to other contexts

In order to assist learners to put what they learn into practice, this study makes use of further core knowledge management steps which are: creation, categorization, storage, sharing, updating and value [13]. In this study the listed above elements are applied to construct a scaffolding M-learning model with knowledge creation process, as shown in Figure 6.

Such a scaffolding m-learning model with knowledge creation process, the learners can understand more about the structure, connections, and combination of knowledge in ecology learning. The sharing and delivery quality of interpreter knowledge is also improved.

C. *Relative Techniques*

1) *Interactive Mechanism*

In this study, the interactive mechanism is an important feature in this framework. In Figure 7, a content delivery process is proposed with the interactive mechanism. The learner inputs personal properties, the system retrieves the environment factors from national weather center to generate an adaptive ecology content and/or provide a suitable route planning to the learner. It is a basic concept of interactive mechanism. An advanced interactive mechanism has to provide feedback function to the learner. It is important because the learner obtains desired adaptive content, the learner's knowledge can be improved, or called evaluated. Through feedback function, the learner's experiences can be fed back to the system, preserved to the database, and then passed down to other learners.

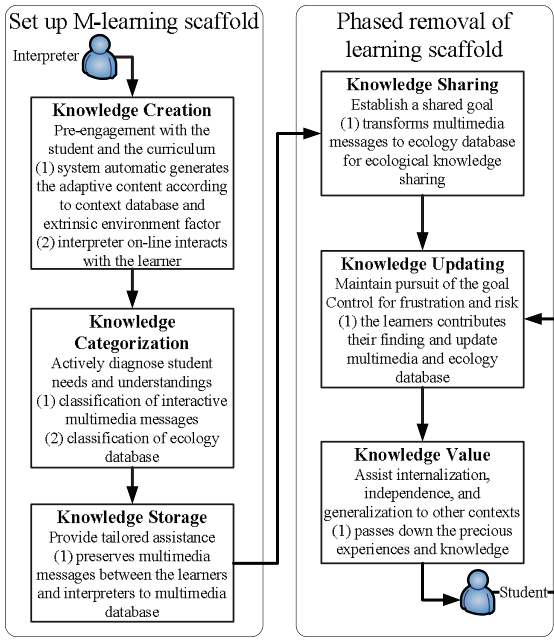

Figure 6 Scaffolding m-learning model with knowledge creation process

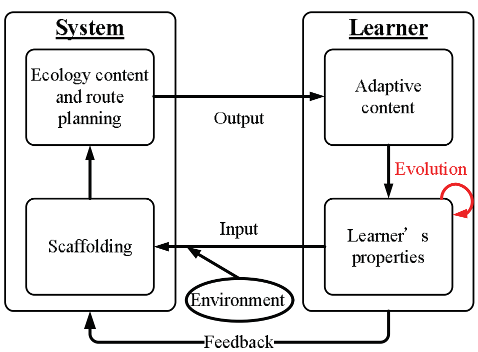

Figure 7 Content delivery process

2) Context-Aware Computing

The basic representation of how the context-awareness system functions as part of the content delivery system is illustrated in Figure 8. A learner with a mobile device is connected to adaptive learning application server, which in turn is linked to the context engine and database. The mobile device passes context state (input), learner context and environment context, obtained from national weather center, user input, and user profile to the context database which then compares this metadata to the content metadata provided by the content database and returns a set of content recommendations. These recommendations are used by the delivery system to determine which content to deliver to the learner, which is packaged as learning object (output), including ecology knowledge, route planning and peers experience.

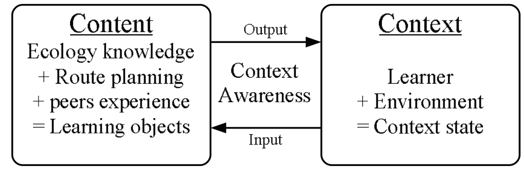

Figure 8 Context-aware schema

The primary purpose of adaptive learning application server is to perform intelligent matching between context metadata (i.e. input, metadata on learner and their setting, real-time environment factors) and content metadata (i.e. output, metadata on ecology knowledge, route planning, interpreter and other learners experience, services and options). By looking for content metadata that matches the metadata of the current context, the system can make recommendations about what content is appropriate. There are two crucial prerequisites for the successful completion of this process. First, available content must be appropriately marked up with a suitable metadata schema. Second, the system must have access to relevant metadata about the context, i.e. the learner's inherent properties and settings and extrinsic environment factors. The ordered list of ranked items of content is passed to content delivery subsystem for use in determining exactly what content should be made available to the user. In this way, the context-awareness system is intended only to make ranked recommendation route list to the system and to the user.

We consider this informal definition of context-awareness as a reference for our work. The LearnerProfile is a computer representation to structure a Learner's inherent properties that contains four components (PhysiologicalFactor, MotiveFactor, Cognition and Orientation).

[LeanerProfile

[PhysiologicalFactor [Age, Gender]]

[MotiveFactor [Attitude, Preference]]

[Cognition [Perceptual knowledge-base, Rational knowledge-base, Misunderstandings]]

[Orientation [Learning period, Problem, Goal]]

]

Any context-aware application or service depends on being able to obtain contextual information from the user's environment or setting. For this system, we anticipate relying on both automated input from sensors and other software and service such as weather server, and input from the user themselves about their state and the state of the world. Some possibilities for automated input include the use of location data derived from tracking a device within a wireless Local Area Network (LAN), GPS, and Bluetooth technology. Users also create their own context, and we anticipate the use of contextual metadata relating to both the learner status and learner profile above [37]. It has formed an important part of research into the design of intelligent interpretation systems.

3) Route Planning Approach

In this study, a route planning approach is proposed in this framework as shown in Figure 9. The route planning process requires two inputs: the learner's properties and the environment factors. The route planning process can be implemented by applying clustering algorithms to generate a suitable route plan for the learner. Clustering analysis or clustering is the process of classifying objects into subsets that have meaning in the context of a particular problem. It is a common technique for statistical data analysis used in many fields, such as machine learning, data mining, pattern recognition and image classification. Through the route planning approach based on clustering algorithm the output route plan provides a suggestion for the learners and assists the learners to enjoy the ecology learning.

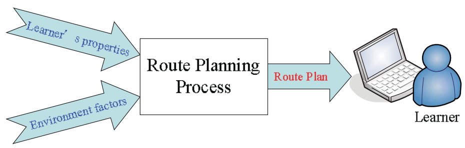

Figure 9 Route planning approach

D. Examples

In this study, all of related ecology guiding information and interactive application can be delivered to learners' portable devices such as netbook, notebook and PDA through mobile telecommunication networks such as HSPA and WiMAX. We assume that the learner plans to have a ecology learning with a netbook which equipped HSPA data card. We provide two scenarios for example.

Scenario 1: If the learner is a new user, the learner has to register his/her properties first. Then the system, the scaffolding ecology m-learning system, will generate a suitable route planning according to his/her properties and current environment factors, which is a good assistance for beginners to find the targets of nature observation. During the ecology learning, if the learner finds out a unknown organism, for example the coastal vegetation community, the learner can on-line requests an assistance and interacts with the interpreter. The learner can make photos for that unknown organism and submits these photos to the interpreter, then the interpreter will search a solution from ecology database and responses the explanation to the learner.

Scenario 2: The learner has registered to the system before and used this system to have an ecology learning. Therefore, the learner's properties has been stored in context database. The system allows the learner to update his/her newest properties such as age, preference or knowledge-base. When the learner uses netbook to connect with internet via HSPA or WiMAX data card and logins this system again, the system will provide a suitable route planning according to learner's properties and current environment factors such location, time and weather, etc. During the ecology learning, the system not only real-time provides ecology information by text, photos or videos, but also informs the learner to pay attention for changing of ecology environment. For example, during September, an amazing number of Chinese goshawks will pass through Hengchun Peninsula, or in October, Gray-faced buzzards, following Chinese goshawks' southbound migrating track, continue to pass through Hengchun Peninsula. The learner can on-line interact with the interpreters by text, photo, or video when events occurred on the way of route. Through this system the learner can learn independently. When the learner finishes his/her ecology learning and gathers new ecology knowledge, he/she can maintain his/her property of knowledge-base in context database. Meanwhile, by using this system the learner can share his/her precious experiences and knowledge of ecology learning to other learners. Furthermore, interactive information of ecology can be stored on multimedia database, shared to learners, and transferred experiences to knowledge of ecology education.

IV. Conclusion and Future Work

In this study an approach is proposed to take scaffolding and context awareness into account for the area of ecology education and learning, and telecommunication technologies are used to connect between the learners, the interpreters and the scaffolding ecology m-learning system through internet. This framework has shown how adaptive functionalities can be embedded into mobile interpretation services for retrieving ecology resources and suitable ecology route plans to enjoy the benefits of ecology guiding service. The interactive messages between the learners and the interpreters through knowledge creation procedure can be preserved, shared and passed down. Eventually, the learners obtain ability of how to learn independently and how to share their precious experiences.

Based on this framework, the integrations of ecology guiding service and user interface and implementations of interactive application, location-based service and multimedia messages are considered. The pilot run will be built up in future work.

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WEB Instruments

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***Abstract*—This paper introduces the concept of a Wi-Fi tag that can be used as an extension of the iLab remote laboratory framework. A Wi-Fi tag has been built by Tag4M of Austin, TX, USA, with the purpose of connecting sensors to the Internet where data is displayed using Web Pages that are posted and can be accessed from anywhere in the world. The Tag4M Wi-Fi tag is tiny and low cost works on battery power, and therefore it is very suitable for student experimentation as an extension of the remote laboratory framework. The tag allows remote students logged in the iLab framework to execute local or home based experiments, and by that brings more hands on capability to the framework. The paper introduces the Tag4M tag, the iLab framework, gives an example of using the iLab framework with the NI ELVIS station, and shows how this type of experimentation can be enriched using the tag to introduce local experimentation where remote students can perform hands-on sensor measurements, create their own web page instruments and also post their web page instruments into the general framework for other remote students to use.**

Keywords - Wi-Fi tag; iLab; Web Page Instrument

I. INTRODUCTION

The concept of Computer Based Instrumentation relies on the continuous advancement of PC technology – processor, memory, etc -, improved resolution and speed of ADCs and DACs, and easiness of programming with LabVIEW, the graphical programming environment used by scientists and engineers to build computer based instruments. The entire idea of computer based instrumentation has been built around LabVIEW. Plug-in computer boards, PXI, cRIO, cDAQ and USB devices have been built all with LabVIEW driver support in order to make the idea of computer based instrument viable. Traditional BOX Instrument based setups have been replaced or upgraded, where suitable, with computer based instruments built with LabVIEW.

Figure 1 The Tag4M Wi-Fi Tag

The concept of Virtual Instrumentation is larger than that of computer based instrumentation. A Virtual Instrument is an instrument that leverages **off-the-shelf technologies** to implement its capabilities for measurement, display, storage and communication. Computer based instruments are limited by the strength of one computer and LabVIEW running on this computer.

This paper defines a new class of virtual instrument which we named WEB Page Instrument or WEB Instrument. WEB Instruments move the concept of virtual instrumentation beyond computer based, beyond LabVIEW and into the Internet space where instruments are built, and shared across the world using web pages. WEB Instruments are built on the power of the Internet network (vs that of a single PC). WEB instruments need Wi-Fi tags (Fig.1) that connect sensors to the internet. Wi-Fi tags benefit from the latest advancements in RFID technology, the improved resolution and speed of ADCs and DACs, components miniaturization and low power requirements. WEB instruments also need the network infrastructure, the Internet, web pages, more advanced web page technology that has not been invented yet, Google search engine, etc, mainstream network technologies. Sensors connected to Wi-Fi tags send data to Access Points that push data further into the Internet to web pages, widgets and other web based applications that reside at IP addresses all over the world. WEB Instruments change the way we acquire data, control and share measurements. WEB Instruments will change the way we teach instrumentation.

II. THE SYSTEM

We have created a tag that links the physical world of measurements with the Internet. Tag4M is an active ultra-low power Wi-Fi tag (Fig.2) that has measurement capabilities. Besides a Wi-Fi radio, the tag contains minimal circuitry for signal conditioning front end to its 14-bit ADC, I/O connectors for signal wiring, and a battery holder. The tag is capable of running for years on a 3V battery if it is programmed with sleep times in the range of 100 seconds.

Figure 2 Wi-Fi Tag

The tag, if connected to sensors will perform two functions:

a) **Measurement.** The tag converts signals coming from sensor(s) into digital values. Tag4M tags are capable of measuring analog signals in 0-10V and 0-0.4V with 14-bit precision, 4-20mA current signals, and digital lines.

b) **Communication** (Wi-Fi). The tag is continuously looking for an Access Point(AP) who it can associate with. If at boot-up or wake-up time the tag finds an AP, then it will send data and get commands to/from this AP. The AP will further send data to the Internet. Somewhere on the Internet network there will be one (or several) computer that is hosting a web page which presents tag data for other client computers to access. The WEB Page is the instrument (Fig.3). Users of the web instrument will connect tags to their local sensors and run the web instrument for local data acquisition, processing, storage and communication.

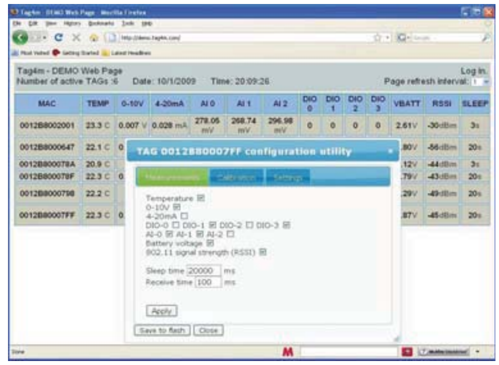


Figure 3 WEB Instrument Page with Configuration Panel

WEB Instruments can be shared in the classroom and school laboratory. In distance learning environments the web infrastructure for class material is located on a server. This infrastructure also includes the lab associated web page instruments. While measurements for this lab are done locally using Wi-Fi tags connected to sensors, the results are posted remotely by web pages inside the lab web infrastructure. This is something new, a new facility of the lab web infrastructure where students can perform local lab related measurements using Wi-Fi tags as hardware extensions of the lab web infrastructure.

III. WEB INSTRUMENTS IN WEB BASED TRAINING WBT

Distance education and traditional face-to-face classroom course delivery are not mutually exclusive. Each has positive aspects that can be maximized and negative aspects that can be minimized by combining them, an approach known as blended learning. Student learning is enhanced when technology is made available that allows for a live learning environment and remote labs are an ideal delivery method for distance education curriculum. The addition of Wi-Fi tags that connect sensors to web pages brings a new and powerful tool to remote labs. Instruments are supplied as web pages hosted by Internet services inside the actual Remote Laboratories (Fig.4).

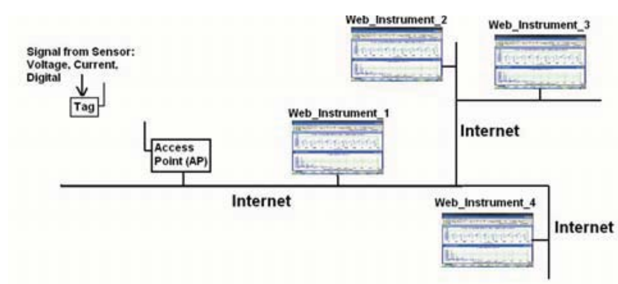


Figure 4 WEB Page Instruments

Academic departments seeking to reach students via distance education course offerings find that some on-line curricula require a traditional hands-on lab model for student evaluation and assessment. The authors solve the problem of providing distance education curriculum and supporting instruction lab components by using a low-cost remote lab based on WEB Instruments.

Web Based Training WBT as an E-learning technology or method is characterized by followings:

- Online computer education
- Education supported by web technologies
- Teaching synchronous and asynchronous online courses
- Studying materials that are mostly available via web browser
- Studying materials that are located anywhere in the world (on the web)
- Opportunities to work inside the virtual classroom

Researchers around the world are thinking about the possibility of enriching the idea of Web Based Training with some elements of local experimentation where students acquire and use small low-cost devices to complete so called "in home" experiments that are part of the weblab topology, described and scheduled inside the Web Based Training labs.

The Internet portal creates an entry gate to the world of information related to a certain subject. The technology of thin-client ("thin-client/server computing") is a model where applications are accessible, administrated and operated fully on the server's side. This technology provides advantages of better administration, access, performance and safety, which help reduce requirements imposed on property owners. But you do not want technology, even the one that is very good and very well administered, to eliminate creative thinking and hands on experimentation, the out-of-the-box element.

Remote laboratories can be **real** or **virtual**. The real model is based on getting information from real experiments, with visualization, providing information in the form of numbers and graphs. The virtual model is based on simulations with the help of software applications like Matlab's server / Simulink, or National Instruments' LabVIEW. Both models can now benefit for a complementary tool, the very low-cost Wi-Fi tag that can be used by the "educational client" in an "at home" type of environment for doing real experiments.

IV. IV iLAB INTRODUCTION

Our team has been involved in the implementation of MITs iLAB technology in Europe. The idea is to offer a standardized Remote Laboratory technology that is adapted and completed with local expertise in order to increase its efficiency.

There are many approaches to the design of Internet-based remote laboratories for education. Early systems required specialized platform-dependent software running at the client computer. Later approaches moved towards browser-enabled technologies for the client, including Java applets, static and dynamic HTML pages, and CGI scripts. HTML-based solutions often result in thin clients with little processing abilities and rely heavily on server-side technologies such as CGI that tightly couple client and server development.

The iLab architecture provides a framework for lab development and deployment. This approach differs from sockets-based solutions by hiding many of the details involved in network communication from the developer.

This was implemented using web-service technology, which provides an object-oriented interface to client/server communication based on traditional method calls that take place over HTTP. In addition, the iLab architecture decouples laboratory-specific operations related to running experiments from the more generic administrative tasks of user authentication, user authorization, group management, and results-storage functionality. The iLab architecture extends the client/server weblab topology by incorporating an additional third tier: the Service Broker, as shown in Fig.5. The Service Broker handles all administrative tasks, thus freeing the server machine (and its developers) from having to implement custom administrative solutions for each different weblab.

However, today experiments have become more and more complex. As a result, the demand for ever more specialized and expensive equipment has increased. Presently, only some large research institutions and perhaps some universities can afford such equipment, and even these more fortunate institutions can only partially have what they need. Remote Laboratories present a viable solution that permit greater access to resources, following ongoing changes in learner interactions online curriculum facilities.

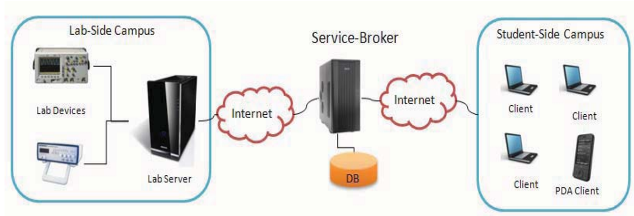


Figure 5 iLAB Shared Arhitecture

Meanwhile, modern learning theories, including constructivism, have emerged and have been employed more and more in Higher Education teaching practices. This trend has significantly modified the traditional learning process model. Students are now expected themselves to build their own interactions with learning experiences as well as materials and different actors that they have to interact with as they complete their curriculum.

In the field of Engineering Education, this suggests a stronger contribution of hands-on approaches in the process of quality of learning. Hands-on approaches are a support of several pedagogical objectives:

- *to compare theory and practice,*
- *to learn how to employ specific tools and devices,*
- *to face real-world situations,*
- *to interact with peers in circumstances that require problem solving skills developed through close*

collaboration, which is characterized by initiative, creativity, etc.

This also emphasizes the need to use experiments within online learning activities, in part, because these online activities permit students to interact multi-culturally across national boundaries, reflecting present and future business, academic and scientific interaction.

V. iLAB AND TAG4M

If we access the web page of the iLAB ServiceBroker and log-in as Guest (http://ilab.mit.edu/ServiceBroker), we will connect to the iLAB labs (Fig.6).

From the list, we choose to connect to the ELVIS laboratory. Using this laboratory as an example, we would like to show how we can add more functionality to the iLab system by having a student behind the iLab client use the Tag4M tag for local experimentation.

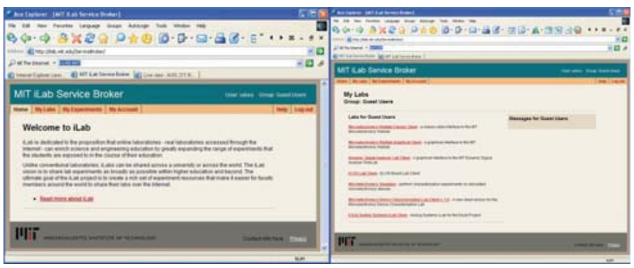


Figure 6 MIT iLab Guest access

Students may be located anywhere and have access to Internet connection so they can log in the ELVIS laboratory (Fig.7) and do some laboratory experimentation as implemented by the iLab platform.

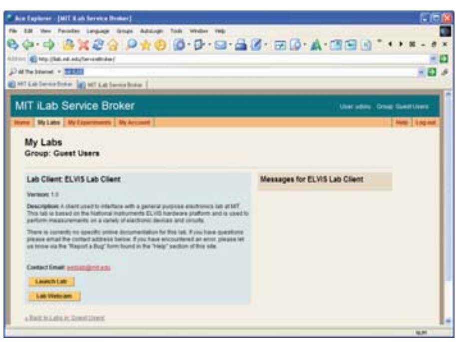


Figure 7 ELVIS Lab Client

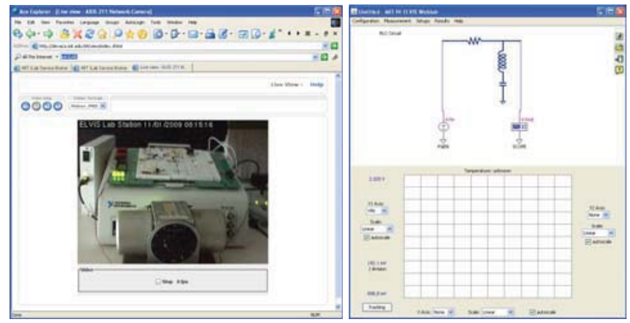
Here, inside the iLab platform we see two types of student user experience:

a) Completely remote experimentation user experience, or

b) Combination between remote and local user experience.

In the first case, the completely remote scenario, the student will simply log into the ELVIS lab and:

- Read the laboratory instruction
- Eventually enter the web site of National Instruments and read about NI ELVIS
- Have a passive look at the experiment using a web-cam (Fig.8a) and launch the experiment (Fig.8b)
- Configure the lab and remotely perform the LRC experiments (Fig.9)



(a) (b)

Figure 8 ELVIS experiment:
(a) web-cam image (b) RLC experiment

In the second case, there is an element of local experimentation inside the iLab content, a web page that can interact with the student and ask him to do some preliminary LOCAL experimentation using a WEB Page Instrument that has been build around the TAG4M tag and which is posted inside the iLab framework.

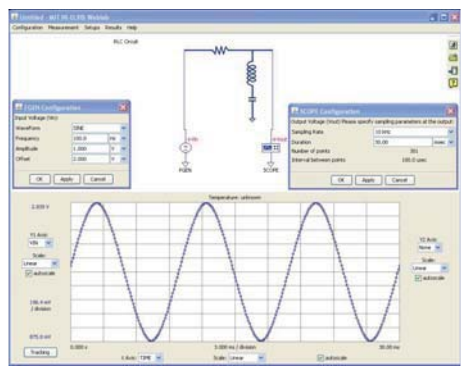


Figure 9 The RLC experiment: configured and executed

This web page instrument allows our student:

- To better understand the laboratory purpose
- To perform some “direct hands-on experiment”

The web page instrument has also a testing function where it will verify student’s knowledge and ability to perform some related home/local based experiment and if the test is passed, will offer the student permission to execute the next steps inside the iLab laboratory.

Referring to Fig.10 below, we give an example of such direct interaction between iLab’s Web Page Instrument and a remote student:

- Ask the student to implement a potential divider

- Fix the values for the resistors (R1 and R2)
- Select a fixed potential (for example the battery potential is measured using the Wi-Fi tag and the reading is sent via an Access Point into the Internet and to the web page instrument which is part of the iLab framework)
- If the WEB Instrument passes the iLab page a correct value then the student is allowed continue the experiment inside the iLab framework.

Using the Wi-F tag as a local extension of the iLab framework, remote students can:

- perform local qualifying experiments
- develop new WEB Page Instruments that are suitable for their experiments or new experiments that the students want to perform
- implement complex LabVIEW applications
- develop more laboratory material
- post their Web Instrument so other students in remote locations can use it with their Wi-Fi tags
- etc.

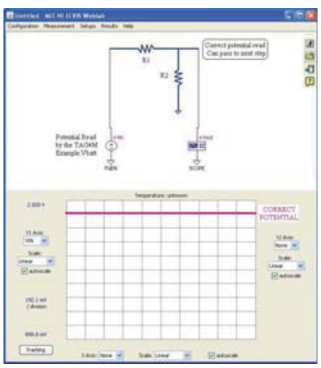


Figure 10 ELVIS + TAG4M experiment

VI. SENSOR BASED ILAB

The iLAB Service Broker may offer a Lab named Tag4M Lab Client. This lab could be structured around types of sensors, so the problem set is sensor based. The iLAB Service Broker for this lab would provide two things:

a) The tag4M Lab Client web page, which is a weblab very similar to the ones currently posted, and

b) One or several Tag4M Wi-Fi tags with sensor extensions to be used in the experiments.

Under this paradigm the tag becomes an extension of the remote lab into student's hands, and this allows for local experimentation with weblab interaction. The following is an example of content for the Tag4M lab.

Tag4M Client: Measurement of Acceleration, Motion, Tilt

1) Description of the type of measurement that is investigated. **Vibration, Motion, Tilt**

2) Description of the sensor used to implement this type of measurement (Fig.11).

ADXL330 3-axis accelerometer with voltage outputs connected to Tag4m Wi-Fi tag.

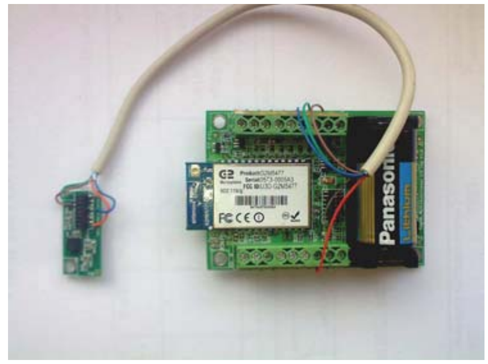


Figure 11 ADXL330 attachment board with TAG4M

3) Schematic or diagram of the circuitry showing how the sensor is connected to a measurement device - Web Page Instrument area that shows Tag MAC and IP address and a graph containing X, Y, and Z voltage levels that correspond to positions of the ADXL330 during the experiment (Fig.12).

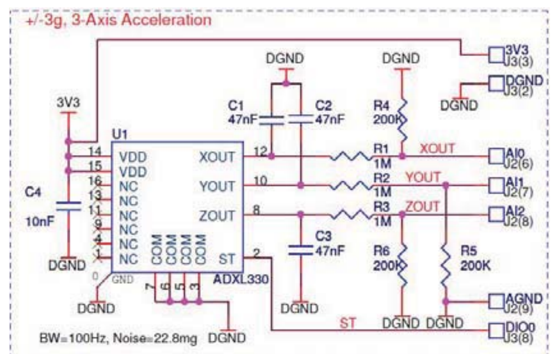


Figure 12 ADXL330 sensor attachment board circuitry

4) The Web Page Instrument is part of the iLab Tag4M Lab Client (Fig.13).

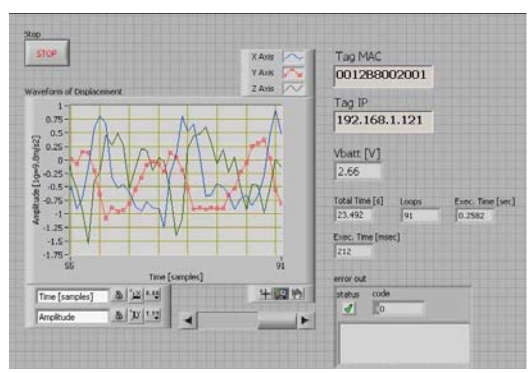


Figure 13 3-Axis Acceleration measurement using the Web Page Instrument provided by the Tag4M Client weblab

The student will physically perform the experiment using a small ADXL330 attachment board connected to the Wi-Fi tag (Fig.11). During the experiment, while the student tilts the attachment board, the tag reads ADXL330 X, Y, and Z axes and sends the data via a local Access Point to the Internet and further to the Web Page Instrument for display.

Similar experiments can be created to measure:

Light intensity (Fig.14)

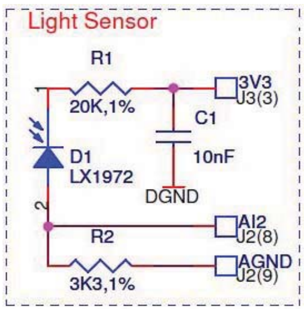


Figure 14 LX1972 sensor attachment board circuitry

Sound (Fig.15)

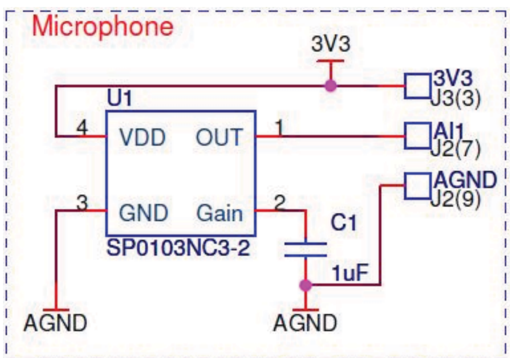


Figure 15 Microphone sensor attachment board circuitry

Temperature and Humidity (16)

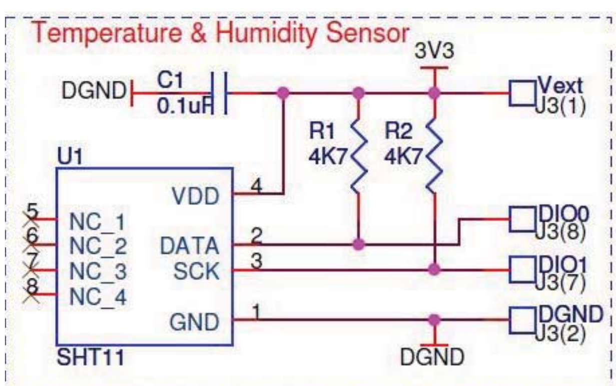


Figure 16 SHT11 sensor attachment board circuitry

LED Pattern (17)

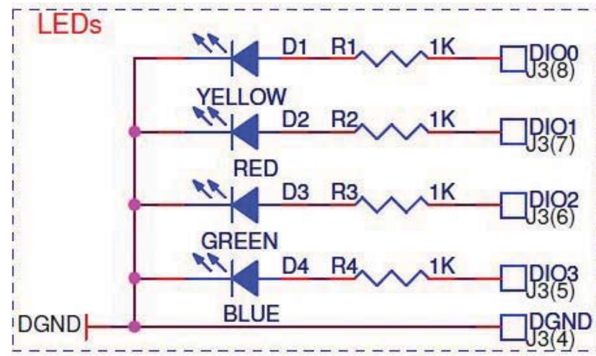


Figure 17 LEDs attachment board circuitry

VII. CONCLUSIONS

A Wi-Fi tag has been built in order to support the concept of a WEB Page Instrument. Tags with Wi-Fi and measurement capabilities are connected to sensors, and measurement data is sent to the Internet network to be posted on web pages. Client computers anywhere on the network can access WEB Instruments to monitor remote experiments or make local measurements using tags connected to local sensors. The concept of WEB instrument moves virtual instrumentation from the computer based space into the Internet networked space. The iLab remote laboratory framework can greatly benefit from using the Wi-Fi tag. Remote students will use the tag as an extension of the remote framework, in order to perform local or "home based" experiments that are part of the general framework but physically executed locally. This is a great combination of virtual experimentation with local flavor. Students can post their web page instruments in the framework for other students in remote locations to use them with their own tags. Work is done currently to create many web page instruments, a community of web page instruments that connect sensors to the Internet.

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Session 03F Area 1: Open Source, Open Standards, and Federated Systems

Open Source Learning Management Systems in E-Learning and Moodle
Aydin, Cansu Cigdem; Tirkes, Guzin
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WikiDIS: a case of collaborative content management system for educative community
Candela, Santiago; García, Carmelo R.; Rivera, Adexe
University of Las Palmas de Gran Canaria (Spain)

An enterprise e-learning solution: The UNED practical case in the EHEA
Castro-Gil, Manuel Alonso; Hernández, Roberto; Hernández, Rocael; Pastor, Rafael; Read, Tim M.; Ros, Salvador
Galileo University (Guatemala); Spanish University for Distance Education-UNED (Spain)

Educative use of simulators in free software for the education of the physics in the engineering programs
Rodríguez-Hernández, Ariel Adolfo
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Open Source Learning Management Systems in E-Learning and Moodle

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Abstract—**In the last decade, the effect of Internet usage in education has increased gradually and new technologies have improved student's learning. By using distance learning tools, the student education can be more flexible with respect to place and time constraints. So, students can access information in every time and everywhere either in libraries or during the lectures. As is widely known that, distance learning is costly, and cost-effectiveness becomes more important as the institutions become large-scale providers of distance education. Cost which is the most important disadvantages of distance learning according to traditional learning environments can be removed with the extensive features of the Open Source Software. Generalizing the usage of Open Source Software will provide development of learning tools and increases the educational quality. As far as the literature is reviewed, not much research has already been conducted about the comparisons of open source learning management systems in distance education. In this study, some analyses and comparisons were made about open source learning management systems and Moodle was outstanding with many features among other LMS that aims to improve the educational quality and include the tools that an e-learning system should have.**

Keywords-component; Moodle, Open Source LMS, Learning Management System, Distance Learning

I. Introduction

The tremendous improvements in information and communication technologies and increase in the use of internet brought lots of opportunities to different fields and also Instructional Technologies. Based on the new technologies, learning environments are able to provide a wide range of educational alternatives for learners. Distance learning is one of these alternatives which became attractive where student and instructor are physically in different location and time [9].

In relation Miller R.L states that, more and more educational institution and companies are adopting distance learning methods to train and develop their employees, because it delivers more training to wide range of people for the fewest cost [5]. What is more, studies show that, it is also effective through including e-learning tools, such as;

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e-learning technologies reduce the learning time requirements by an average of 50 percent and retention rate of the trainees greater with e-Learning including interactive than with a solely classroom based model [11].

Learning management System (LMS) which have a significant role in distance learning is also known as the Virtual Learning Environment (VLE) or Learning Platform. Hall defines an LMS as: "software that automates the administration of training events [2]. All Learning Management Systems manage the log-in of registered users, manage course catalogues, record data from learners, and provide reports to management." The definitions of LMS systems and related terms encountered in this article are discussed in further details in the article Online Education: Discussion and Definition of Terms [11].

Many organizations are using learning management systems (LMS) to support and to improve learning within their institutions. According to Observatory on Borderless Higher Education, some higher education institutions continue to develop in-house systems or buy into open source alternatives, but an ever-larger majority is purchasing licenses for proprietary platforms [1]. However, the open source LMS may have an impact on the future LMS market with its cost effectiveness and advanced features.

Open Source Software

In a distance learning process, open source software can be used in many different phases such as application software that performs learning content preparation and in LMS which provides learning content presentation in a web based environment and as web server software (APACHE e.g.).

Due to the advantages of distance learning, schools and companies are adopting these new learning technologies and increasing their investments in it. However, along with the advantages, installation and support costs appear to be a disadvantage compared to a traditional learning environment. These disadvantages can be reduced to a great extent by the use of open source software which provides further gains. OpenOffice, StarOffice, KDE Office, GNU Office software, which are under

open source content authoring tools, are among the most widely used content preparation tools.
Statistical studies show that open source web server software is again found mostly preferred and widely used in learning content presentation in a web based environment such as (Netcraft Survey, 2008)[6]. Figure 1 shows that open source application and web server software are used in an open source e-learning system.

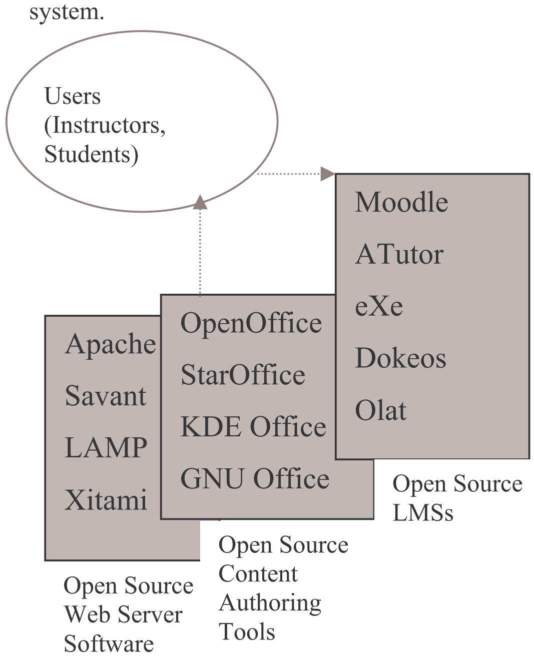

Figure 1. Open Source Application and Web Server Software

Advantages of Open Source Software

Most debated advantages and disadvantages of open source (OSC) software are; total cost, other financial and forensic subjects [8].
Advantages of using OSC software can be summarized as follows [8]:

There is no single feature on which the future of the software depends: Open source architecture enables the user to take away the software company dependency risk that originated the code chosen to stop development and increase maintenance and development fees.

Confidence:

Popular OSC software is examined by many developers and software experts so; it is filtered and cleaned of errors. In this way, with the increase in quality, the fundamental aim of software production and the process of usage, Users confidence in the software increases.

Sensitivity and flexibility for User Requirements:

OSC software is often updated more frequently than proprietary software. Most of the time, these changes reflect the needs of the user and the developer community.

The Support of Innovation:

The Production process of OSC software is improved by a broader range of diverse and creative ideas. In this way, each developer has equal rights to reflect his own innovative thoughts to the product.

Security:

OSC software provides security according to the level of user requirements but usually not at the level of commercial software. Users with commercial software do not have access to the underlying contents of the code, so they do not have a definite knowledge of their security.

In a study of Computer Science Corporation (CSC), total cost of ownership has been defined after the comparison between OSC software and proprietary software as follows [7]:

- Hardware costs (contains purchasing cost and maintenance).
- Direct software costs (contains purchasing cost, support and maintenance).
- Indirect software costs (especially license management).
- Personnel costs.
- Supporting costs.
- Breakdown period costs.

Requirements for Learning Management System in an E-Learning Process

A learning management system is defined as software that has been used in a learning content presentation which has a significant role and complexity in e-learning environment. An advanced e-learning system has to comply with the following requirements [3,4]:

- Compatibility and the ability to work with other LMS.
- Content management ability such as Electronic filing and file management,
- How the learning content is created and managed as a “learning object”,
- Reusability of the content (Content compatibility like Scorm, AIIC, IMS),
- Rapid content creation, distribution, integration and authorizing tools,
- Support for the tools using in content creation such as (Dreamweaver, Flash, Word, PowerPoint),
- Performance and extendibility of the environment,
- Multi-Language Support

In the light of the features mentioned above, when these headings are analyzed in detail, as shown in tables below, the analysis shows that the success rate and the rate of wide-spread usage goes up in similar order to the number of these features included in the LMS,. These features can be listed as follows:

- Creating content in different input format (Scorm, IMS Content Package, MPEg file, Office file, JavaScript, PHP),
- Including tools for content development and management of content installation (Modular Structure),
- Database support,
- Advanced search and header hiding ability,
- XML support to work with different systems,
- Compatibility with industrial standards (AICC and SCORM e.g.),
- Video Conferencing support,
- Exam module, Online exam (test based question preparation),
- Student education process prosecution,
- Multiple language support,
- Calendar,
- Backup support,
- Chat tool,
- Whiteboard,
- Group work, debate forums,
- Ease of system installation,
- Survey adding,
- System requirements (the less the requirements are the easier it is to set-up).

In this study, the mostly preferred four LMSs are selected among from fifty free and open source LMSs on the web site of UNESCO [16]. The features of three LMS's (ATUTOR, DOKEOS, OLAT) have been analyzed by using the full Access demo versions accessed from their web sites and a detailed analysis carried out by creating courses on each LMS. For Moodle LMS, by taking advantages of the trials on usage in different projects have been used to prepare the following table.

TABLE I. COMPARISON OF OPEN SOURCE LEARNING MANAGEMENT SYSTEMS

OPEN SOURCE LEARNING MANAGEMENT SYSTEM	MOODLE	ATutor [6]	DOKEOS [7, 8]	OLAT [9]
Support and Compatibility to Standards (AICC, SCORM)	Scorm and IMS Content Package support.	Scorm and IMS Content Package support	Scorm and IMS Content Package support. Ability to import different LMSs course that are in Scorm Format.	Scorm, IMS Content Package and QTI support
Multiple Language Support	77 different foreign language support	64 different foreign language support	5 different foreign language support	14 different foreign language support

Online Exam	10 different type question support exams can be prepared according to time, date and duration constraints. Includes "Secure window" option for exams.	8 different type question support Exams can be prepared according to time, date and duration constraints.	6 different type question support Exams can not be prepared according to time, date and duration constraints.	4 different type question support Exams can not be prepared according to time, date and duration constraints.
XML support	Exists	Exists	Does not exist	Does not exist
CHAT and GROUP WORK	Includes chat and group creating tools. Each user can work in his/her own group.	Includes chat and group creating tools.	Includes chat and group creating tools.	Does not include chat and group creating tools. Course content can be seperated according to goups
Ease of installation and maintenance	Installation and maintenance documents can be reached from Moodle.org and different sites.	Not enough installation and maintenance documents	Includes only flash based installation and introduction documents in their home site.	Not enough installation and maintenance documents
The follow-up of student's learning process	Visited links, contents, sources and all activities done by visitors can be seen in with date details.	Visited links and content usage by user can be seen statistically..	Visited links and content usage by user can be seen statistically..	Visited links, contents, sources and all activities done by visitors can be seen in with date details
Including content development and content authoring/editing tools ,modularity.	There is an Html based content editor. Course pages can be editted as Html pages and new application can be added as a modules.	There is an Html based content editor. Does not have a modular structure.	There is anHtml based content editor. Does not have a modular structure.	There is anHtml based content editor. Does not have a modular structure.
User Authentication	Rather than its own database, the data can be hold in different servers such as ; LDAP,IMAP..	User passwords holds in its database.	User passwords holds in its database.	User passwords holds in its database.
Survey and forum support	Exists	Exists	Exists	Exists

Calender	Course can be followed on calendar. Courses can be arranged weekly.	Does not exist	Does not exist	There is a calendar that can be used as agenda.
Video Conference Support	Exists. Also holds ”White Board” application. (For Moodle version 1.6 and upper WiziQ live Class Module existsl)	Does not exist	100 user can connect at the same time and ”White Board” application does not exist..	Does not exist
Backup Tools	System can get backup automatically in required time and date. Every module can be backup seperately.	All course content can be backup manually. Modules can not be backup seperately.	All course content can be backup manually. Modules can not be backup seperately.	All course content can be backup manually. Modules can not be backup seperately.
System Requirements	Apache, MySQL, PHP	Apache, MySQL, PHP	Apache, MySQL and PHP.	Java 1.5, Tomcat 5, MySQL 4.1, Apache 2.0 and OpenFire 3.3
User Interface and ease of usage	Extremely good. According to their profile, users can change their information and menus with a user interface that gives opportunity to design. Themes/skins allow for easy font/color/layout, etc. to suit local needs	Owns a good menu design. Very sleek, easily modified by individual user (e.g., menu locations, icons vs. text, font, colors)	Owns a good menu design.	Owns a complicated menu design.
Multiple Input Support (Multimedia etc.)	There is Scorm, IMS Content Package, mpeg, mov, mp3, flash, Office file, JavaScript based content support.	There is Scorm,IMS Content Package,Office file, mpeg,mov, mp3, flash support.	There is Scorm, Office file, IMS Content Package, mpeg, flash support.	No Multimedia support
Frequency of Usage	73.000 registered users	23,925 registered users	600 registered organizations	150 registered organizations

In Table I, it can easily be analyzed that, Moodle and ATutor stand out with their features among other open source LMSs. Moodle is the only LMS which has wider options with different access possibilities, modular structure, and advanced backup tools.

Comparisons show that, Moodle and OLAT have the ability to view full user logging and tracking and activity reports for each student are available with graphs and details about each module (last access, number of times read) as well as a detailed "story" of each student involvement including postings etc. on one page.

As a learning communication tool, Moodle LMS owns debade forums, file transfer, e-mail, calender and white board and real time chatting options.

As different from other LMSs ,in moodle there are different access possibilities from different groups for the administrators. These are administrators, educators, students and guests accounts.

Educators can save students text files that are limited only for course usage or students can save their documents by themselves.

Educators can put discussions and course activity to special dates however system can check these dates and synchronize course dates according to the corporate calender.

Moodle and ATUTOR have an advanced online exam module with time, date and duration constraints. As shown in Figure 1, with advanced exam and assessment modules, educators can create questions in many formats such as; Multiple-choice questions supporting single or multiple answers, Short Answer questions (words or phrases), True-False questions, Matching questions, Numerical questions (with permitted ranges), Embedded-answer questions (close style) with answers within passages of text. The answer to each question includes separate feedback.

Educators have the ability to view full user logging and tracking - activity reports for each student are available with graphs and details about each module (last access, number of times read) as well as a detailed "story" of each students involvement including postings etc on one page.

There are tree course format in the software such as by week, by topic or a discussion-focussed social format. XML support option in software adds a technical flexibility providing a basic syntax that can be used to share information between different kinds of applications. As shown in table above, Moodle and Atutor have the XML support. When system requirements are analyzed, OLAT is the only LMS having a difficult installation process because of the program requirements.

Analysis show that language is an important issue having an impact on the selection and use of LMS systems according to Paulsen's data [10]. With the 77 language support, and the numerical data in the frequency of usage as shown in Table I proves why Moodle is the most preferred open source LMS
Addition to the features listed above, only Moodle and Dokeos have "video conferencing" support within other softwares. With this software, virtual class application can be performed by using tools such as; online chat, file transferring (.pdf, .swf, .doc, .docx, .xls, .xlsx, .ppt, ve .pps), white-board application, two side video and voice transfer on a specified date and time. A screenshot from mentioned application can be seen in Figure 1 [10].

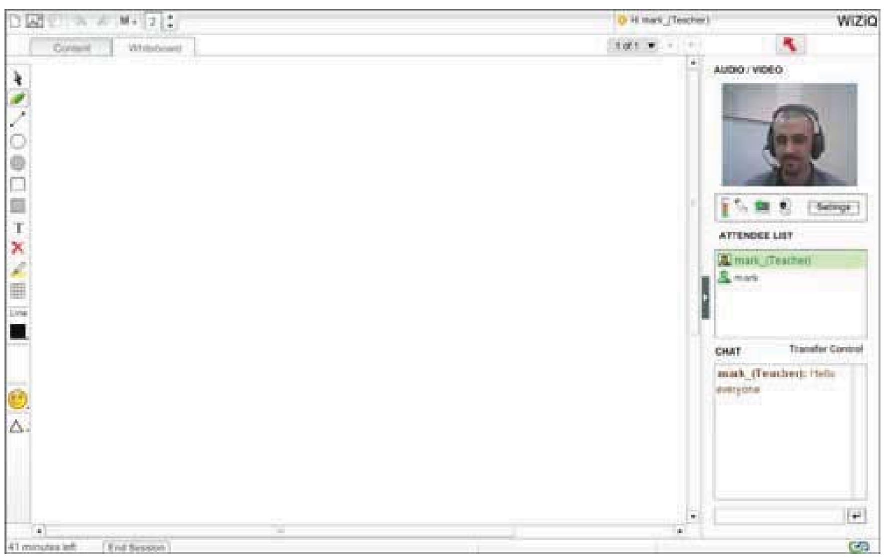

Figure 1 Video Conference and White Board Application Screen Shoot

Multimedia support in this software add a significant value to especially language teaching. As shown in Figure 2, with advanced exam and assessment modules, educators can create questions in many format.

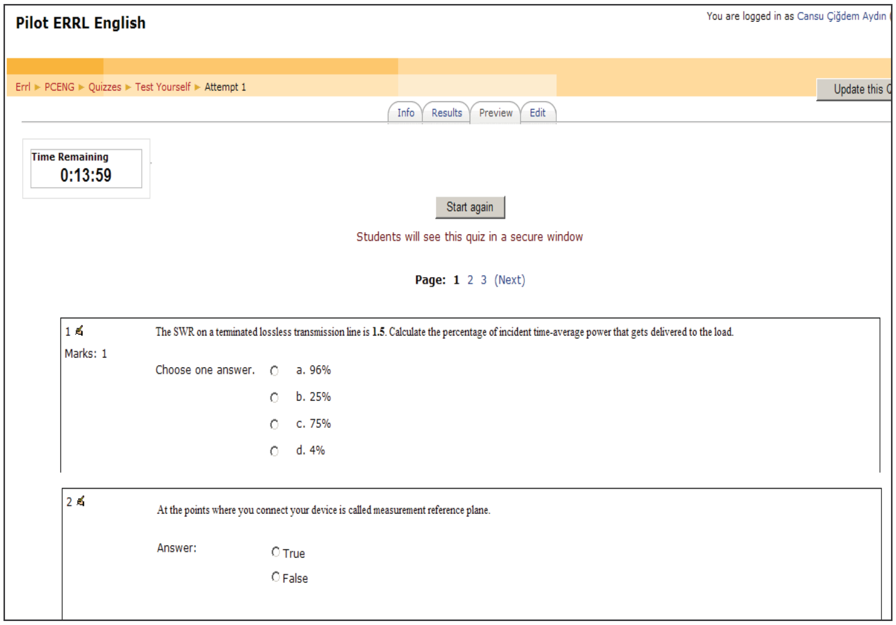

Figure 2. General Look of an Exam Module

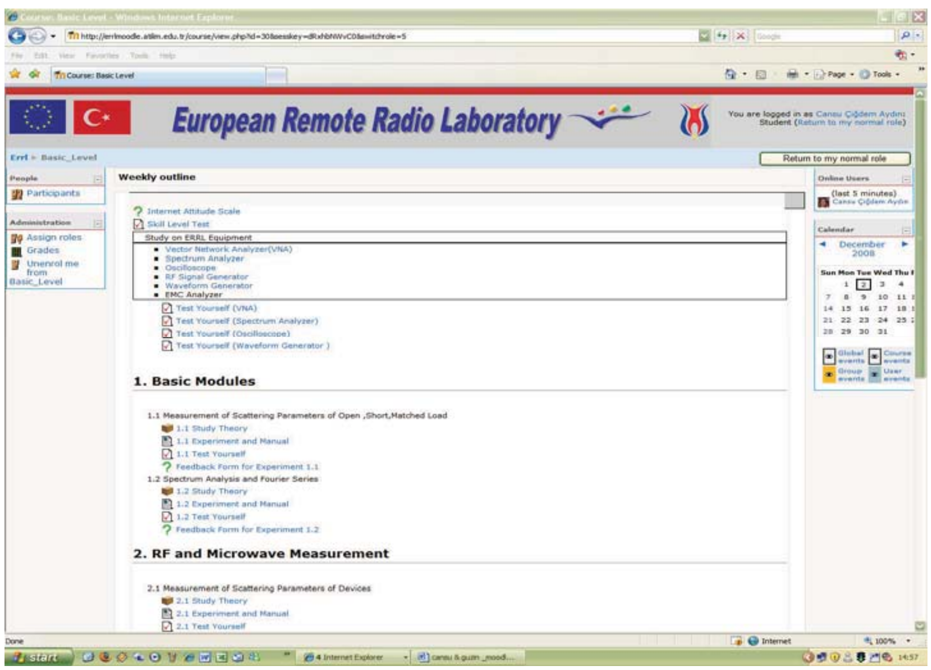

Figure 3. Weekly Course Schedule

CONCLUSION

In this study, open source LMSs were analyzed and it was observed that Moodle LMS among other LMSs, include many features that improve pedagogical quality and many needed tools that an e-learning system should have.

On the other hand, all three LMSs offer sufficient basic functions for their use as an LMS in an educational organization.

However, Moodle appears to present a clear advantage practically in all the features compared. Briefly put, these are:

(1) The modular design of the Moodle environment guarantees its flexibility: depending on the modules employed, it can

lend support to any type of teaching style or educational mode.

(2) A further asset resulting from its modular design and its greater attention to user interface is Moodle's superior rate of usability, compared with its competitors. In the case of the environment, the fact that it has a wider range of options does not make its use more complicated at all.

(3) A wider range of user authentication options, ease of installation and maintenance in Moodle increase the frequency of usage.

All in all, it is possible to state that; due to the fast improvements of distance-learning, generalization of the use of open source software would provide the development of learning tools and educational quality. Also, the cost, which is the biggest advantage of e-learning rather than traditional learning environments, is removed by the use of open source e-learning tools.

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WikiDIS: a case of collaborative content management system for educative community

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Abstract—**In this paper we describe a collaborative content management system based on Wiki Technology. This system, named WikiDIS, is designed to be used on a collaborative way by all persons who are part of an educational community (students, teachers, administrative staff, etc.) Functionalities of WikiDIS are friendly editing, editing and publishing workflows adapted to different types of users and communications facilities. The main functionalities and design aspects are explained in this work.**

Keywords-Wwb technology; Wiki technology; collaborative work; content management systems.

I. Introduction

Coinciding with the popularity of Internet, the Content Management Systems (CMS) has been developed during the last years. A CMS is a tool, that based on web technology, provides an environment where the creating, editing, managing of multimedia documents can be made on a friendly, reliable and secure way. These tools facilitate the tasks related to the web administration, offering functionalities such as: WYSIWYG editors, user communication (email, chats, forums, etc), resources for contents downloading and loading, web personalization and styles, language translation, etc. Nowadays there are multiple tools of this type that offers us these functionalities; one of them is the Wiki system that additionally has an important characteristic consisting in to permit the collaborative work of the users. A Wiki site is a collaborative web space where the user can create, edit and publish web contents on interactive, friendly and quickly way. With the Wiki technology, the contents of a Wiki site can be edited on a collaborative way using an Internet browser and a simple notation for contents formatting, indexing, etc. Additionally, this technology incorporates tools for versions controls of the contents permitting the pages restoration. The ideology of Wiki is democratic, it means that the contents changes in a Wiki site can be visible immediately but, generally, often there is a user who is responsible of verifying of the changes in order to permit only the publication of correct contents. The origin of Wiki is the community of the software designers [1], when the designers used shared information spaces in order to develop and discuss programming patterns. In 1995 Ward Cunningham created WikiWikiWeb, the first Wiki space, and he defined the Wiki of the following way "the simplest online database that could possibly work ". Later, in January 2001, the founders of the Nupedia project, Jimbo Wales and Larry Sanger, decided to use Wiki to develop the encyclopedia project, creating of this way Wikipedia the biggest Wiki space of the world. Initially, they used the Wiki tool called UseMod, but later they decided to develop a new Wiki tool that they called MediaWiki, being the base of many Wiki spaces nowadays.

In this paper we describe the functionalities and main aspects about the design of a collaborative content management system developed by us that we have called WikiDIS. This tool, based on Wiki technology and more specifically on MediaWiki, permits the editing and publishing of contents related to the activities of an educational and academic environment on a collaborative way. Specifically, WikiDIS has been developed to use by the community of the Department of Computer Science and Systems of the University of Las Palmas de Gran Canaria (DIS), in this context community means all the people which participate in an educational community, such as: pupils, teachers, administrative and services staff, academic authority, etc.

II. Wiki distributions

Multiple distributions of Wiki systems exist nowadays. These can be distinguished according to the type of organization they are designed, for example for personal or organizational use. Another classification can be established depending on the type of tools they have, for example version control of contents, security facilities, upload of different type of archives, etc. At last, another classification can be done depending on the technology used to develop the wiki distribution, for example:

- Java language has been used for Clearspace [2], JSPWiki [3], Kerika[4], Mindquarry [5] distributions.
- The technology .NET Framework has been used for FlexWiki [6], WWWiki [7] and ScrewTurn [8].
- The distributions Cliki [9] and SVNWiki [10] have been developed using LISP.
- Perl language for Twiki [11], UseModWiki [12] and WikiWikiWeb [13] distributions.

- The Wiki systems TikiWiki [14], DekiWiki [15] and MediaWiki [16] are based on PHP technology.
- Phyton has been used to develop the MoinMoin [17], OghamWiki [18] and Trac [19].
- Instiki [20] and Ruwiki [21] have been developed using Ruby.

Some of these Wiki distributions are not free, specifically Clearspace, Kerika. Others are software under GPL or GNU license, for example JSPWiki, ScrewTurn, Twiki, SVNWiki, MediaWiki and TikiWiki or under license which permits the free use, for example Cliki (MIT license). From the point of view of the relevance of the Wiki site, we must cite UseMod, used to develop Wikipedia, Trac that is used by NASA's Jet Propulsion Laboratory and TikiWiki to develop collaborative workspaces in educative context, Aulawiki [22]. We have chosen MediaWiki because it has a very important property in order to incorporate new functionalities, this property consist of the development, installations and using of new software components named extensions. Additionally, MediaWiki has an organization very structured and configurable, supporting Latex to edit mathematic expressions and different language generators.

A reference of specific Wiki system for educational contexts is the Aulawiki, having as the more important functionality the support of collaborative workspaces named Tiki Workspaces. In these systems, two main roles are defined: pupils and teachers; existing others roles: registered associated to all the registered users, anonymous for not registered users and owner to represent the owner of a workspace.The participants of a workspace can be organized in groups to work in different subjects. Additionally, the available resources in each workspace can be configured between a set of tools such as: Blog, Wiki page, file gallery, etc.

III. Goals and Requirements of WikiDIS

The main objective of WikiDIS project is to implements a collaborative content management system, based on free software, which permits to automate the documents flow generated in an educational university organization. The collaborative requirement means that the system must permit to all the people who integrate the educational community can produce, a controlled way, the contents for the information system of organization. Therefore, the system must to have a friendly user interfaces that permits to the users the creation, edition and publishing of contents regardless of the level of technical knowledge of the user.

Conceptually, we have identified three main entities in an educational organization:

- Participants that are: pupils, teachers and administrative and services staff. In the case of the DIS, the numbers of member of each category are 1200 pupils, 120 teachers and 2 administrative and service staff.
- Academic government that is formed by directive staff and commissions; in the DIS the directive staff is formed by the following figures: director, secretary and laboratory chief, existing 2 permanent commissions that are the academic commission and the economic commission.
- Academic demand configured by the academic qualifications and the subjects of their curriculums. The DIS develops its activity in 103 subjects organized in 13 curriculums of academic qualifications.

The contents are generated as consequences of realizing of tasks by the members belong to the categories of participants and academic governments. These tasks can be grouped in the following sets or categories:

- To coordinate and developing of the subjects teaching and learning. All the participants of the educational community execute tasks belong to this categories; pupils in tasks of learning, teachers in tasks of teaching and people belong to academic government and administrative staff in tasks of coordination of the teaching and learning activity.
- To elaborate the teaching project of each subject. This set of tasks are executed by participants belonging to the entities of teachers, academic government and administrative and services staff.
- To organize, coordinate and promote the activities related to research, technological development and innovation. The executors of this category of tasks are the same as reported in the previous category.
- To promote and developing the educational innovation. Like the first set of tasks, people belonging to all the type of participant entities can execute tasks belonging to this category.
- Management of the material, economic and personal resources assigned to the DIS. Basically, this set of tasks is executed by participants belonging to the entities of academic government and administrative and services staff.
- To elaborate, updating and publishing the internal regulations of the DIS. People belonging to the entities of academic government and administrative and services staff are the executors of this set of tasks.
- To develop and maintain the information system of the DIS. The participants are the same as the previous category.

In order to access to the different contents associated to these tasks, depending of its category, each participant have a set of functionalities and privileges. The main challenges of the WikiDIS project were:

- To improve the organization of contents of the Wiki system, that is lineal based on the concept of paper, in order to support more complex structures of contents required in an educational organizations, being frequent hierarchical organization of contents. To meet this challenge, we have introduced two new concepts named subject and prefix to organize the contents, now the contents are organized in subjects and the subjects are structured in papers. To allow sharing papers between subjects, we use the concept of prefix of the following way: each subject and paper has a set of prefixes associated; a paper is shared by all the subjects that have at least one common prefix. Thus, we can say that conceptually the contents in our model are structured as a undirected graph where the nodes represent subjects and paper and the arcs represent the relationship "to have a common prefix", having each arc a name that matches the prefix name that represents.

- To reconcile the democratic principle for the collaborative use of the contents Wiki Systems with the controlled and collaborative access to the contents required in an educational environment. Specifically, in Wiki systems the contents are organized in papers, each paper has a administrator user who decides if others users have the privilege to modify the paper. In an educational environment, the contents are structured in different subjects and each subject has at least one administrator who decides, between the users that can access, the type of privilege of each of them.

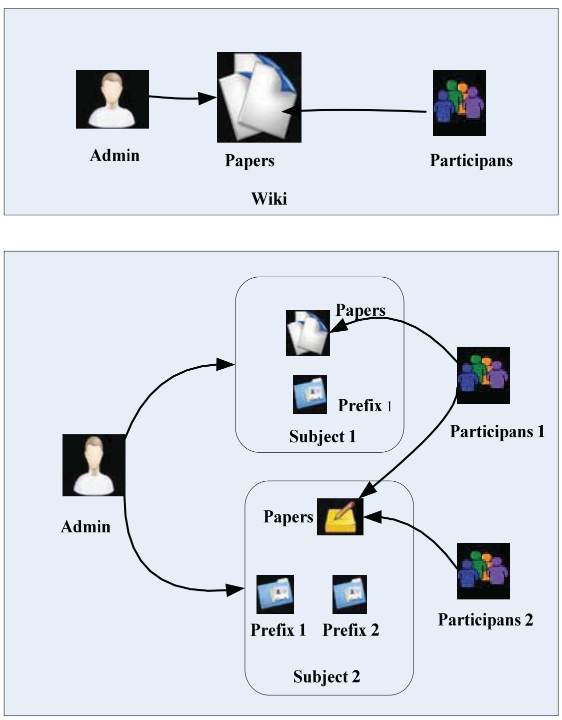

Figure 1. Wiki organization versus WikiDIS organization

IV. System Description

WikiDIS is a evolution of the software tool called MediaWiki (GPL license software) for this reason WikiDIS has functionalities such as: friendly editing of the web contents, using WYSIWG editor, building and publishing workflows adapted to the different users profiles, tools to translate for different languages (about 100), control of versions and control of expired contents. Moreover, it incorporates resources for user communication (email, chat, forums) and tools for loading and unloading of multimedia contents.

In WikiDIS all the elements that participate in the educational and academic activities are represented by entities, these entities are structured in three categories: people (pupils, teachers, administrative staff, etc.), academic management (directive staff, academic council, commissions, etc.) and subjects. The entities have different types of privileges for editing, publishing and visualizing of contents depending on the activity performed, for example: organizing, coordinating and controlling of the subjects teaching, resources management related to the educational and academic activities, building, updating and publishing of documents (manuals, procedures, teaching projects, regulations, etc.). Additionally, WikiDIS supports the contents management related to the teaching and learning tasks of the subjects realized by pupils and teachers.

To achieve all the design goals, we have developed and integrated new modules in the MediaWiki architecture, specifically in the named logical level and data level. In the logical level, new PHP scripts and extensions have been added in order to incorporate new contents and functionalities to the database, for example the content management required by subjects and groups of them . Moreover, several files have been modified to support the characteristics of the workflows of the academic and educational tasks. In the data level of MediaWiki, we have modified the design of the database by the incorporation new tables and fields. As a result WikiDIS has the same structure of MediaWik that is a layered structure [23], but its architecture is different because it incorporates new components and functionalities, for example new sections named prefixes, subjects and chat, are available in WikiDIS . For these reasons, we can affirm that WikiDIS is an evolution of MediaWiki; this evolution is specifically oriented to the educational environment.

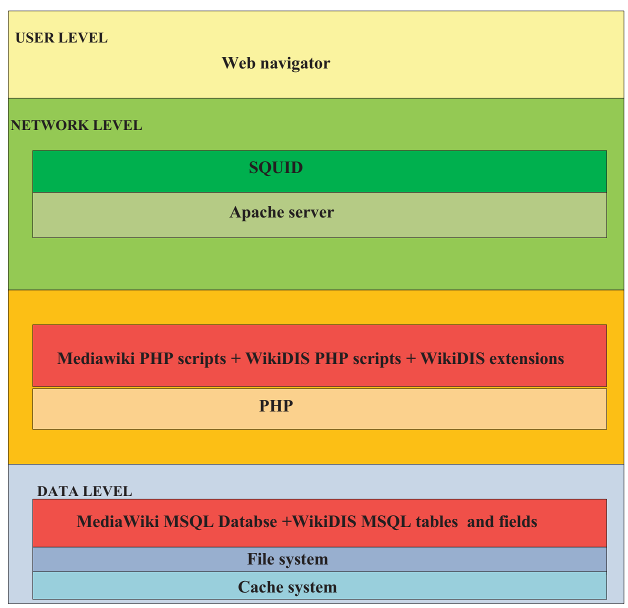

Figure 2. WikiDIS architecture

Following, the new modules developed for WikiDIS will be described. To build these components, we have used a set of development tools, specifically HMTL, PHP, JAVASCRIPT and AJAX for elements based on web technology and MSQL as database tool.

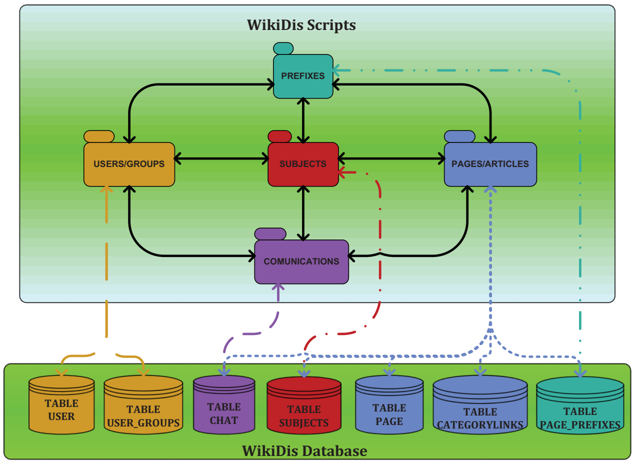

Figure 3. Relations between scripts and data in WikiDis

A. Users and groups module

This module manages the users of the system, here the registers of the users are performed, and the interaction with existing prefixes and grouping in different set of users called groups, being also the management of these groups responsibility of this module. As consequence of these functionalities, the users can be related to groups, subjects and to set to them the privileges of use of the system. Additionally to the two groups defined initially in MediaWiki, WikiDIS has three main groups defined initially: pupils, teachers and administrative and service staff. To set these three groups in WikiDIS initially and to garantee that these cannot be modified, we have introduced the specification of these new initial groups in the file named DefaultSettings.php, although in the specifications of MediaWiki the modifications of this file is not recommended. To permit the automatic creation of user from CVS format file, another modification has been made in MediaWiki, it consist in to develop a new extension based on the existing extension named Import Users created by Rouslan Zenetl y Yuriy Ilkiv [24]. By this new functionality we can set the users of the system (pupils, teachers and administrative and service staff) automatically from electronic document coming of the educative administration. Another new extension, named User Administration, has been developed to facilitate the management of the personal data of the users and the groups and subject related with them. To administrate the groups of the system, a new script has been developed, named Groups Administration and based on the existing extension Prefix Security created by Borut Tomažin [25], using this new extension the administrators of the system, they can create prefixes sets, for example related with subjects, with different privileges for different users and groups . Finally, in order to have additional information about users, new attributes are incorporated in the user registers of the database as well as their methods of insertion in the database.

B. Prefixes module

This module supports the controlling access of the different pages of the system. WikiDIS incorporates a new prefix named “Prefix Administration” which is based on the “Prefix Security” of MediaWiki mentioned in the previous point. Using this WikiDIS module, we can specify different type of access to the pages, for different users and groups, incorporating a contents management controlling based on user, pages of themes (for example subjects) and prefixes which permits the prefix administration (creating, modifying and erasing of prefixes) and the setting of relationship between prefixes and users . To achieve these functionalities WikiDIS incorporate a new file named “PageRestrictionHooks.ph” by this module, when a user tries to access a page, the system verifies if the user has the proper privilege of access , informing to the user in case of access denied. Figure 3 show us the relationship between this module and the rest main modules of WikiDIS. This figure shows us how the prefix manager is related with the user manager to control the users and prefixes groups. In the figure we can see how each subject has at least a specific prefix, of this way the access control can be achieved. The relationship between pages and prefixes is set indirectly; by the access privileges of all pages that have titles with some prefix declared in the system as restricted prefix. . Finally, also the database is used by this module, specifically the file PageRestrictionsHook and the table page_prefixes, to control the privileges of the users specified in the prefixes.

C. Subject module

A main entity of WikiDIs is the entity subject because all the contents associated with the learning and teaching process are organized around this entity, for example all the subjects of the academic qualifications have an instance of this type. This module is responsible of the management of all the instances of this entity, an extension named Subject Administration that has been developed to do this task. Additionally, a new class, named subject, has been necessary to implement in MediaWiki and like other new modules of MediaWiki it is based on the existing of another component of MediaWiki, specifically the class named user. The class subject has the following attributes:

- mId to represent a unique identification of the subject instance.
- mName: this is the symbolic name of the subject instance.
- mPrefixSubject: this is the prefix of the subject, using this attribute the control access to all the pages related with this instance of subject is achieved
- mKnowledgearea: it identifies the knowledge area of the instance subject. The Knowledge area is an administrative concept, used in the Spanish university teaching system. By the use of this term we can relate subjects belonging to the same administrative area.
- mShift to indicate the teaching timetable of the instance subject.
- mDescription: that is a description of the instance.

- mWebPage specifies a set of web sites related with the subject represented by the instance
- mReadPermissionTeachers controls the read privilege of the teachers, using the prefixes manager.
- mEditPermissionTeachers controls the modification privileges of the teachers, using the prefixes manager.
- mReadPermissionStudents controls the read privileges of the pupils, using the prefixes manager.
- mEditPermissionStudents controls the modification privilege of the pupils, using the prefixes manager.

Aditionally, associated with this subject class, a set of methods have been developed. These are:

- For creating and loading of instances of subjects: load, loadFromId, loadDefaults, loadFromDatabase, newFromName, clearInstanceCache, createNew, addToDatabase, saveSettings, createSubjectPageInitial, createSubjectCategory. By this set of methods, we can create and load the instances of the subject class, storing the data fields in the database.
- For editing the attributes of the instances: getCanonicalName, getID, setID, getName, setName, getGroupPermissions, getGroupName, getGroupMember, getAllGroups, getImplicitGroups, getGroupPage, getPrefixSubject, setPrefixSubject, getKnowledgeArea, setKnowledgeArea, getShift, setShift, getDescription, setDescription, getTitulation, setTitulation, getWebPage, setWebPage. . By this set of methods, we can obtain and modify the instances attributes of the subject class. The methods get to obtain and the methods set to modify the attributes.

The figure 3 shows us the relationships of the subject manager with other managers of WikiDIS. As we can see in the figure, to relate users, teachers and groups of them with subjects, this module is connected with the user manager. Also, the connection between this module and the communication module is represent in the figure, by this relationship WikiDIS provides a new functionality consist of virtual tutorials of teachers and pupil accessible in each page of a subject by a new section named communication section. To end the explanation of this module, we must to say that each subject has a set of pages and papers related by categories, these categories are set when the subject is created therefore there are two entities to control the pages of the subjects that are the prefix and the category. To facilitate the management of subject pages, WikiDIS incorporates a mechanism that every time that a subject is created a main page of the subject is incorporated automatically to the system and providing pages templates based on text formats of Wiki also.

D. Communication module

As in the cases of the above modules and in order to support the facilities of chat and virtual tutorial, WikiDIS has a new tool named Chat Action Hook based on the existing chat tool named Chatty developed in PHP by Marco Olivo [26]. Each page or paper belonging to a subject has a tab, using this resource the user can access to this resource. By this tool the users, related by a common subject, who have the proper privileges can communicate on a spontaneously way. The relationships between this module and other WikiDIS modules are illustrated in the figure 3. The relationship between this module and the user module is made to validate that the user has the proper privileges to participate in the chat and tutorial and to authenticate the chat messages. The relationship between this module and the pages module is established in order to register information about the pages for which the communication between users. Nowadays only the communications made in the last 24 hours is stored in the system.

E. Pages and papers module

This module is responsible of the creation and edition of pages and papers. To implement the conceptual organization of the contents around to the subjects and to speed the access to the pages, WikiDIS use the concept of category to organize the pages of the system. WikiDIS incorporates two existing extension named Require Category and Manage Categories created by Hendrik Brummermann [27] and Florian Mayrhuber [28] respectively. The first extension is used to guarantee that each pages belong at least one category and the second is used to facilitated the categorization of the papers, consisting this extension in three parts: a section to visualize all the existing categories of the system, a section to create new categories and finally a section to visualize the categories of the paper. This organization of the pages permits to the system collets papers that have some common aspect. The figure 3 show us that this module is connected with all the previous modules, the reasons of these connections have been explained previously. Finally we must comment that the connection of the manager of pages and papers with the database is made to manage properly all the information and to carry out all the cheeks of pages and papers, using the following database tables: page, subjects, chat, categorylinks and page prefixes.

F. Other developed components

Additionally to the modules modified or created previously explained, WikiDIS has a set of new modules in order to achieve specific functionalities of WikiDIS. These modules are:

- Main pages module: In a Wiki site the main page of the site is common for any use that access to the site. In WikiDIS when a user tries to access to the system, this module checks if the user is a system registered user. If the user is not registered in the system, then a common main page is showed for the not registered user. Otherwise, the system shows to the user the main page associated of the main category that user belongs. In the system there are three main categories of users (pupils, teachers and administrative and service staff). This module of main pages management is based on the extension named Group Portal created by Tim Laqua [29]. Additionally, this module checks if the user has administration privileges in order to provide specific administration options to the main page.

Figure 4. Initial page of WikiDIS

- User interface: In order to achieve a simple, usable, attractive and intuitive user interface we have developed a new interface based on other existing of MediaWiki named MonoBook and Modern. The first was selected because of its intuitive aspect and the second because of its attractive aspect and it is more readable for the user. A result of this new interface is the new skin for WikiDIS.

V. WIKIDIS IN ACTION

The execution of WikiDIS is illustrated in this section. To use WikiDIS, the first step consist of the user authentication, the figure 4 shows how to introduce the user name and the passwordDepending on the role of the user authenticated an initial page is presented. Te figure 5 illustrates this page for a user with the role of administrator or teacher. For all the kind of user, WikiDIS provides options for content management and preferences, additionally administration of entities (users, group of users, prefixes and subjects) are provided for the case of users with the role of administrator or teacher. This distinction of roles between users is an important difference compared to other wiki distributions where basically the roles are administrator, editor and reader.

The initial page for administrators and teachers has six sections, these are:

- My subjects: using this section the teacher can manage the subjects related with him. If teacher is not related with any subject, then this section does not appear.
- Other managements: using it, the user can access to some miscellanea functionalities, such as: search, files upload, my contributions, special pages, etc.
- User management: all the functionalities related to the users can be accessed by this section.
- Subject management: this section permits to access to all the functionalities related with subject admin.
- Group and prefixes management: using this section the users with role of teacher or administrator can manage the groups and prefixes.
- Profiles: using this section the user can manage his profiles and preferences to use the applications.

If the user has the role of pupil, then the initial page only will have the sections: My subjects, other managements and profiles.

- 

Figure 5. Mainl page for adminsitartor or teacher

To facilitate the entities management WikiDIS provides a set of facilities. For example, in the figure 6 the page to create a user is illustrated, by this page the common fields for any user are introduced.

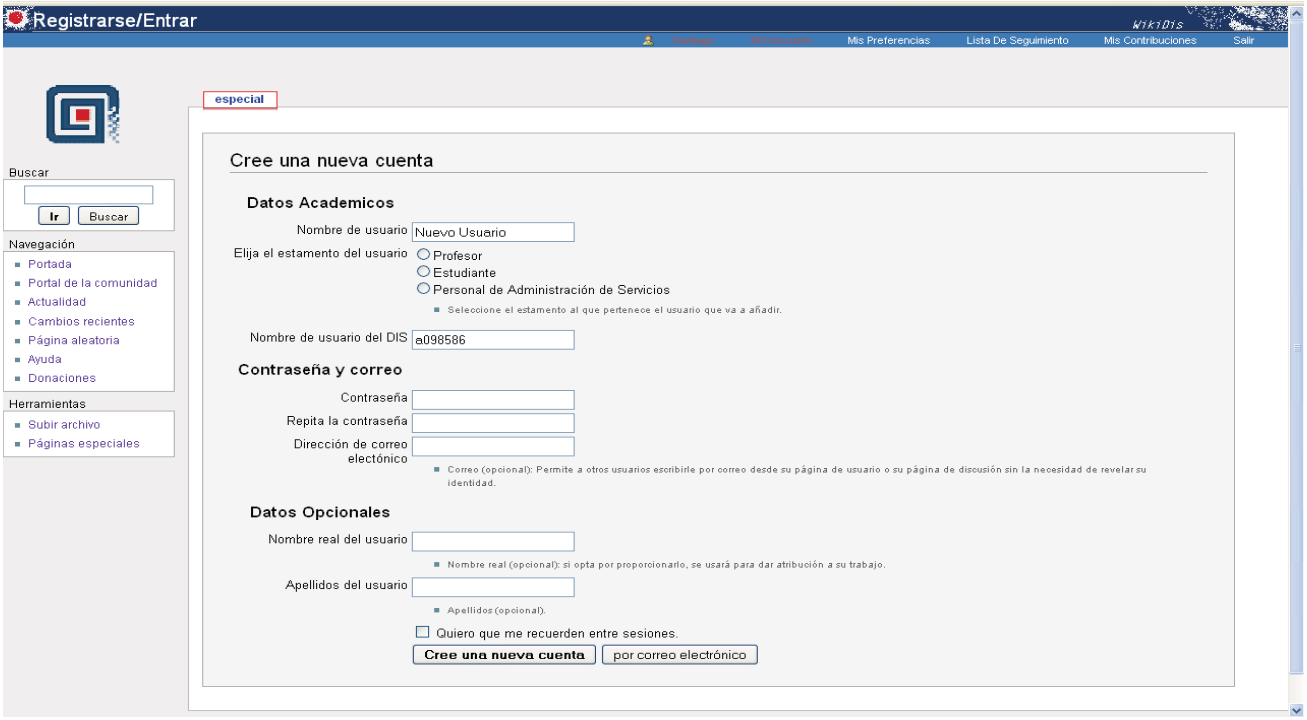

Figure 6. Page for seeting the common atributes of a new user

Depending on the role of the new user, specific pages are presented to complete the setting of attributes of the new user.

The figure 7 presents the specific page for a new user with the role of pupil.

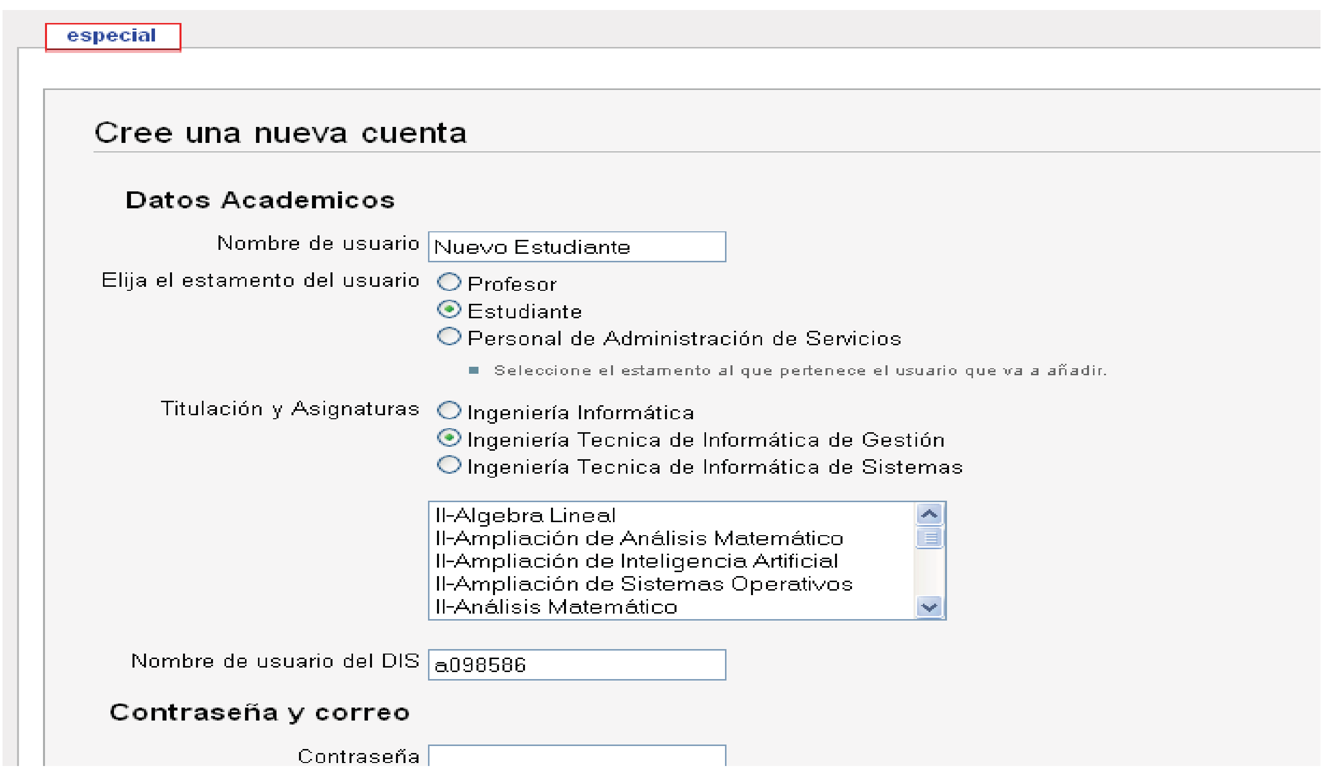

Figure 7. Page for seeting the specific atributes of a pupil

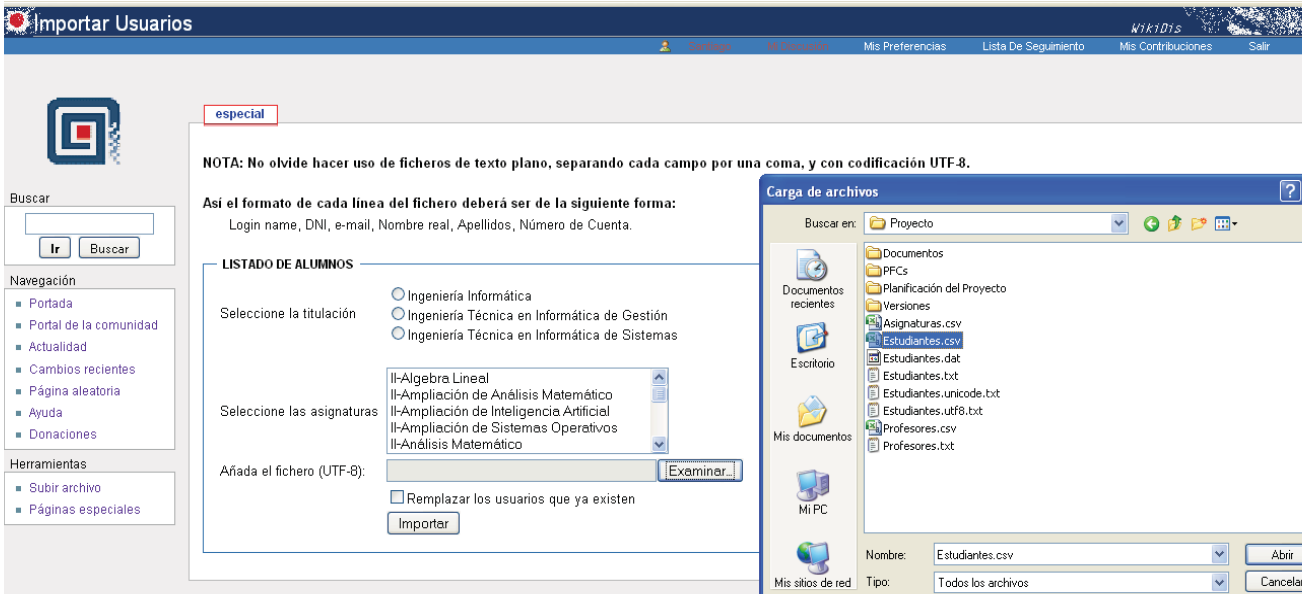

Figure 8. Page to create automatically users by the users import facility

To create a set of users on automatic way, WikiDIS provides a facility to import users. In the figure 7 the page to use this functionality is presented.

Additionally others facilities for entities management are provides by WikiDIS, specifically for the management of users groups, prefixes and subjects. For example, the management of the subjects is achieved by two main pages. The first page is showed in the figure 9, in this page all the subjects that can be accessed by the user are presented.

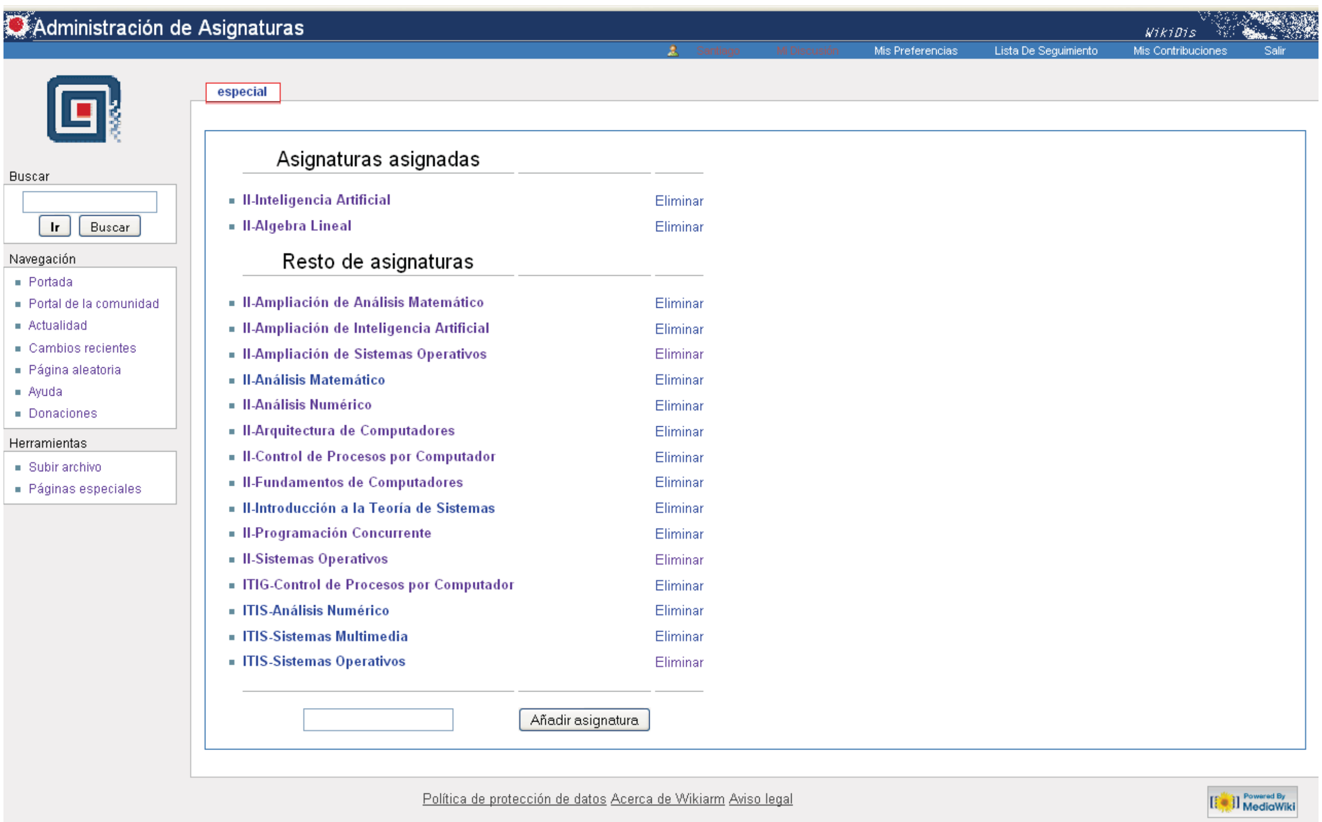

Figure 9. Page to access to the subjects management

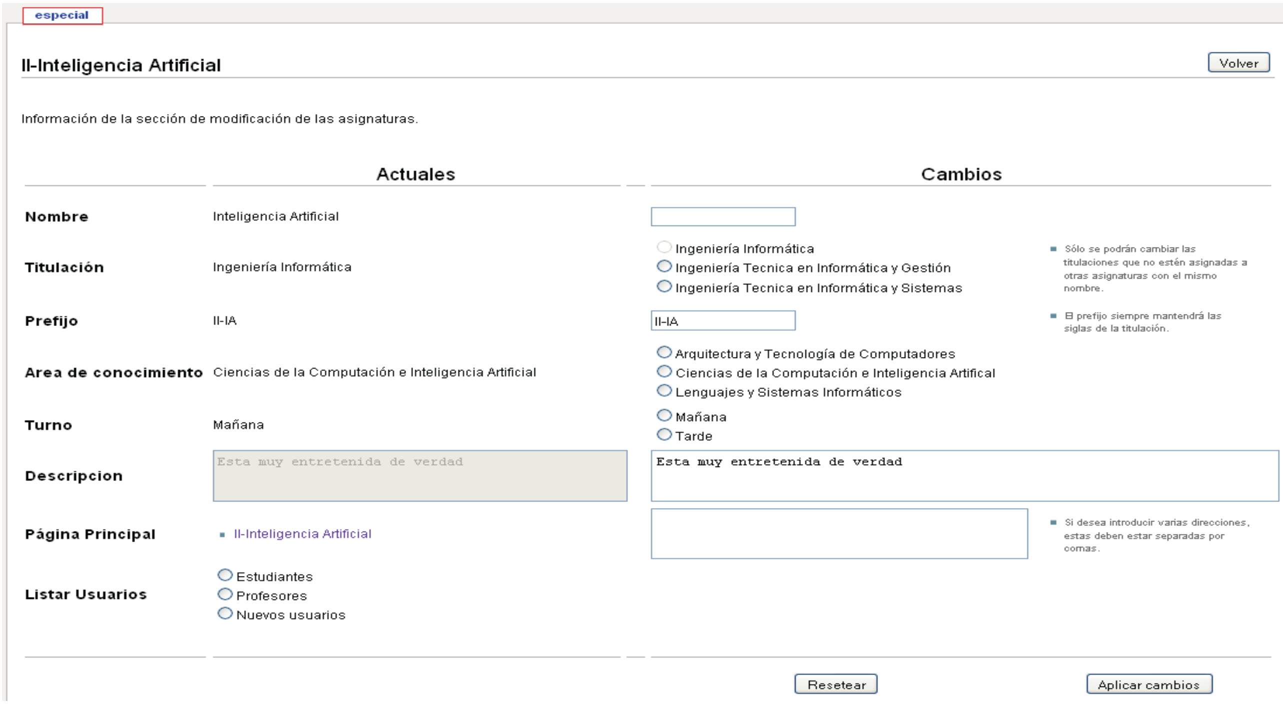

Figure 10. Page for setting the specific atributes of a subject

Selecting one of these subjects, then the second page is showed. Figure 10 illustrates this page; all the subject attributes can be accessed by this page.

This organization of content based on prefixes, subjects and articles is another significant difference of WikiDIS with respect to common distributions of wiki. In these distributions the content organization of a subject is carried through papers, so that content associated with a subject can be seen as a two-level tree where leaf nodes are papers. The content organization of WikiDIS is based on the concepts of prefix, subject and paper allows a more flexible structure, where the papers can be part of different subjects, that is sharing content, leading to a content organization as a graph

Finally, the WikiDIS communication module is illustrated. This module permits the chatting between users that can access to a specific paper. The figure 11 presents the chat page.

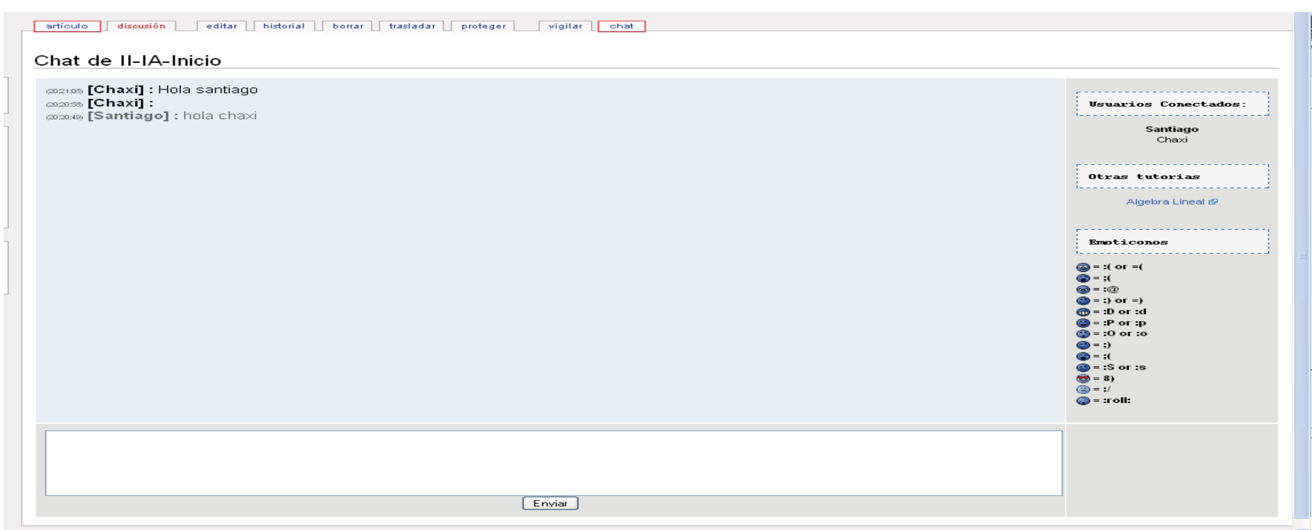

Figure 11. Page for chating about a paper

VI. CONCLUSIONS AND FUTURE WORKS

In this paper a collaborative contents manager system named WikiDIS has been presented, this system an evolution of the Wiki technology tool named MediaWiki. We can affirm as a main conclusion of the WikiDIS project that is possible to develop a collaborative contents manager system for a university educational organization based on Wiki technology. This system is able to support the controlled production and access to the contents associated to the work flow executed by all the participants of a university educational community. Although nowadays WikiDIS has been used in a university context, this system could be used in other educative contexts. Because WikiDIS is based on MediaWiki, WikiDIS has all the functionalities and advantages of the Wiki systems. One of these advantages consists of the possibility of adding new components and functionalities. In a general educative context and as future work, our group will try to integrate to WikiDIS in other very popular educative telematics platforms like Moodle. In the specific context of the computing science, a next goal to achieve is to incorporate resources to support collaborative and concurrent processes for learning and teaching in subject such as development of programs in different programming languages.

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An enterprise e-learning solution:

The practical case of the UNED in the EHEA

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Abstract—**In this paper, the European Higher Education Area (EHEA) adapted technological model is presented, developed in order to provide the e-learning solution for the new grades of the Spanish University for Distance Education (UNED). The transition of UNED's e-learning users to a new platform must focus on user experiences, so WebCT (used in the university from the beginning as its e-learning platform) and Moodle (open source elearning platform with numerous implementations in other universities) were analyzed from a user's point of view. This analysis allowed a set of interfaces/tools to be defined in order to fulfil the user requirements for the UNED enterprise e-learning system, called aLF (active Learning Framework). Actually, the new version of aLF has implemented the new improvements in order to start a successful transition.**

Keywords-user experience; e-learning platforms; enterprise e-learning system; adaptation; customization

I. INTRODUCTION

The Spanish University for Distance Education, UNED [1], is the largest public distance education university in Spain with over 200,000 students, 1400 lecturers and 2000 administrative staff. It has been in existence for more than 30 years. Since it is a distance education university students do not come to a central campus to receive their teaching. They attend regional study centres. There are currently over 60 of these study centres distributed throughout Spain and Europe. As well as the lecturers the university also has 6900 tutors working in these study centres. The tutors are an important figure in the teaching process because quite often they are the main contact the student has with the university. They provide the students with support in many ways, for example, giving taught classes, leading laboratory sessions, and helping to resolve any problems the students may have with the subject being studied.

One of the key features that sets the UNED apart from other distance universities is its consistent commitment to innovation, both methodological and technological. As such, it is evident that ICT (Information and Communication Technologies) has always had an important role within the UNED. Over the years its use has grown and currently forms an important part of the university's activities. As well as the online teaching activities it is also used as part of the administration process (where the UNED is moving towards the position of being a paperless university), admissions (where more than 90% of student admissions are being undertaken via Internet), and examinations (where the exams are no longer transported to the local study centres on paper but as encrypted electronic files). However, without a doubt the most important application of ICT in the university has been the development of our own online community-based learning platform, aLF [2], for use in our virtual campus.

When the UNED's virtual campus was started in the year 2000, a commercial e-learning platform was initially used. This e-learning platform was WebCT [3]. With time it became evident that this system was not sufficiently flexible for the university's needs, and hence the platform aLF (active Learning Framework, a system being developed by researchers in the School of Computer Science) was gradually introduced as a substitute. With the appearance of the EHEA (European Higher Education Area), modifications were required for aLF, but represented only a part of ongoing development activities, and did not by any means imply a drastic restructuring or rebuild of the platform or its tools.

These days it is very common for standard face-to-face universities, and other academic institutions, to offer forms of e-learning. As such, they are able with very little work, to configure existing online systems to provide the technological infrastructure for these taught courses. Since the student numbers in these cases are typically very small, and the online teaching is typically complementary to their main teaching activities, it does not matter that the underlying technological infrastructure is used or not enterprise by nature. In the UNED, however, due to its very distance education-based nature, all ICT used has to be EIS (Enterprise Information Systems). Any EIS should by definition be robust, scalable, OS portable, and interoperable with other systems. The currently popular PHP-based e-learning platforms (Moodle [4] is the most popular solution in the open software area) do not fulfil these requirements, and hence, any application for large student numbers requires custom ad hock solutions, which is far from perfect. Since aLF is built over dotLRN [5], which is an EIS, it is inherently robust, scalable, etc., as any system of this type should be.

However, in the UNED, all the e-learning users are accustomed to working with the WebCT environment so the portlet based interface of aLF (the standard view in web applications) was not easy for them to use. Focusing on the UNED user's experience, a new interface has been developed adding some icons/tools functionalities of WebCT 4.x. Furthermore, the influence of Moodle users in the methodological approach of the UNED lead to the development of a new planning tool that behaves like the Moodle tool. With this tool, the UNED Moodle users will be more at ease with the e-learning platform. Additionally, more improvements based on the WebCT and Moodle experiences were added. In the following sections the EHEA fundamentals and their importance for the UNED, and its need for a robust enterprise learning management system, will be presented. Subsequently, the tools developed in order to get a full new interface and tools oriented to the EHEA specifications, and based upon best practices taken from WebCT (the UNED's Learning Management System before 2009) and Moodle (a lot of users have been working with it), will be detailed.

II. EHEA SPECIFICACIONS

The EHEA directives present the evaluation of personal and group activity as the main feature of an EHEA e-learning space. So, a lecturer must build a planning model of a course based on autonomous tasks and collaborative activities between students. The first feature consists of providing an organizer tool to define the course structure, so from this organizer the student has a clear view of his/her objectives and who is going to undertake collaborative work in order to achieve good academic performance. In aLF this feature is provided by the planning tool (a Moodle-like tool). The planning tool has a user-friendly interface for thematic or weekly blocks that presents an organized view of the different resources of the e-learning platform.

Another problem is how to provide a unified view of content (like the content table of WebCT) and activities, avoiding the use of hyperlinks (created by professors, so mistakes are common) from content to activities. The idea is to have a navigation model using didactic units (like e-books) easy to define and use. These didactic units have activity sections in order to add platform resources, so for a lecturer it is easy to declare the planning of a course and add his/her own content integrated together with the platform resources (activities, assessments, forums, chats and so on). In order to provide this feature, a new tool called Content was developed to fulfill the requirements. In the following sections these tools will be explained.

III. WHY ENTERPRISE E-LEARNING?

The UNED has nearly 200,000 e-learning users in almost 5,700 learning communities (courses and working communities). So, the performance of the e-learning solution is very important for the university and its users. In Table 1, some important statistics are detailed in order to get an idea of the requirements the need to be taken into account for the e-learning platform. aLF is based on the OpenACS/.LRN [5] framework toolkit, and open source solution for enterprise systems which fulfill these requirements [6],[7] & [8]. Also, the toolkit has the property of clustering in order to provide a 24 hours service with no down time, so it is easy to add new front-ends in order to achieve the performance and availability of the solution.

As an example, a snapshot from Google Analytics is shown in Figure 1. The e-learning platform (November 2009) has been around 700,000 pages served (as peak) and 25,844 users viewing learning pages (as peak) during that period.

IV. ALF SERVICES AND USABILITY ISSUES

In order to provide a customized solution for the university, the development of aLF has been focused on two aspects: the addition of collaborative interaction tools (first problem) and to provide several workspaces where to share information from different groups, classes or communities (second problem). So, from the user's viewpoint, aLF provides a large variety of tools organized around three clearly distinguished workspaces: a personal one, the communities (to which the user belongs) and the courses (being undertaken by the user). The services offered, therefore, depend on the environment in which the user's interaction takes place:

- Communities: the organization of different types of work groups (teaching teams, research projects, various associations, departments, faculties, etc.) is made possible. To this end, several communication tools are offered (forums with notification services in e-mail and news), work management (documents shared with version and access right control, links of interest to the group and surveys) and task sequencing (agenda with appointments and weekly task planning).
- Courses: apart from the general services already mentioned for the communities, the following are included: document management (tasks, summaries, notes, course guides, and frequently asked questions), activity planning (weekly planning integrated with the course tasks) and several resources (links and shared course files, inclusion and edition of web pages with the course contents, exams, management of students and marks, etc.).

TABLE I. SOME DATA FROM OCTOBER 2009

Statistics Item	Value
Hits per day	2,000,000
Hits per month	50,000,000
Page views per day	550,000
Page views per month	15,000,000
Daily single users	15,000
Average users connected	400
Average response time per hour (in seconds)	2 s
Peak of connected users & hits	900 users & 3,200,000 hits/day
Number of communities (either subiste, or dotlrn classes, sub groups and/or communities)	5,700
Number of registered users	210,000
Number of active users per year	115,000 last year | 50,000 last mont

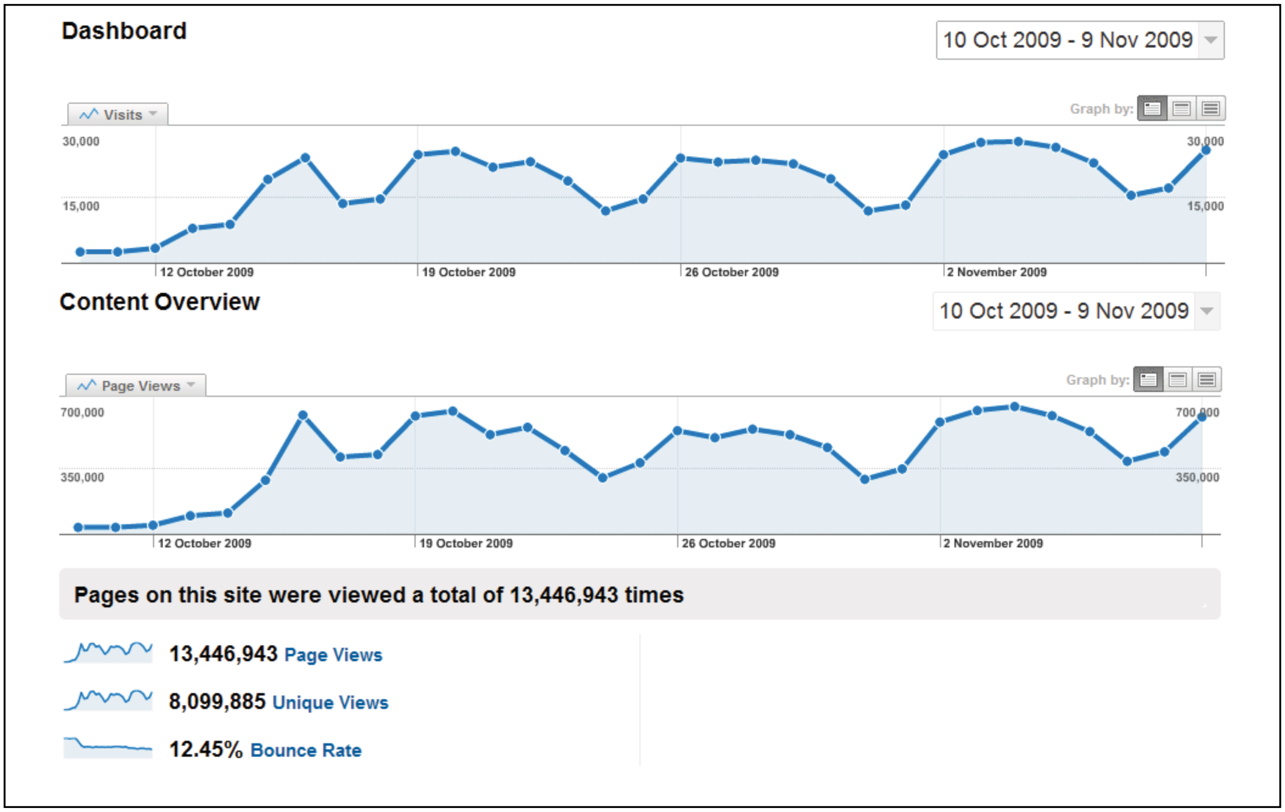

Figure 1. Snapshot from Google Analitycs

- Users: all aLF users have an agenda, a space for documents, links of interest and personal pages in the work area of any user/teacher/student which integrates with the rest of the services offered in the different communities or courses to which the user belongs. Furthermore, tools are offered for different types of users. Hence, the administrators and teachers have specific tools for following the work undertaken by each user and for each type of user. For example, statistics can be accessed by value and by user in each community or course.

In each case, when a user enters aLF, he first accesses his personal workspace ("my portal"), from which he can efficiently access all the novelties that have taken place in any of the communities and courses to which he may belong. In fact, one of the most highly valued aspects by users is the possibility of efficiently accessing any novelty, i.e., a new file added in such groups, the new lines in the agenda, the messages in the forums, the tasks and notes in the courses, the news, etc. Another question related to the management of novelties is the fact that the aLF forums can be managed through automatic response notification services. This allows user to be warned of any novelty appearing in a forum, without the need to be connected to the platform. Furthermore, the user can choose whether to receive news sent by a specific user (e.g., the teacher) about a certain subject and/or to receive an instant warning or report of the novelties that have taken place in the last few days.

Finally, aLF facilitates the organization of the interconnections between the different workspaces, both those related to the personal and collaborative work in the different communities and courses, and those related to the groups and subgroups defined in such communities and courses.

As has been seen above, aLF provides several advantages: customization adapted to the UNED methodological model; a robust and scalable solution focused on corporative environments; and an integrated portal environment for virtual communities (classes and work groups). There are several systems used in different institutions. Maybe two are the most referenced: WebCT [3] and Moodle [4]. The UNED has been using WebCT since the year 2000. WebCT supports big institutions (like the UNED) and it is a consolidated solution for enterprise environment. Moodle is an open software solution which has a great projection, but it does not have implementations on big systems (the UNED has nearly 200,000 users). Furthermore, both of these solutions are based upon the concept of course with no interaction between courses and group works, and no sharing of educational services between courses. aLF provides these features, sharing all the objects available in the groups (calendar entries, tasks, assessments, news and so on) publishing them in different group targets (for example, from a personal space it is possible to share, not to copy, owned documents to a class, allowing to rich the learning environment [9]).

So, aLF is oriented to users but the interface used it was not pleasant for users and it was necessary to get "best practices" from two well know platforms (WebCT, implanted in UNED, and Moodle, due to its impact in the open source e-learning platform world) in order to assure a smooth management change.

V. WEBCT BEST PRACTICES

WebCT was implanted in the year 2000 (when the UNED started to work with Learning Management Systems), so a lot of practices and experience has been gained using it. In 2008, an exhaustive work of requirements analysis was undertaken to get all the mayor functionalities that university lecturers wanted to be in a new platform (and not present in aLF). The main features were:

- A simple content table. aLF did not have a tool similar to the WebCT Content Table tool.
- Icon based interface. All the users are used to work with the icon interface provided by WebCT so a first section on courses was developed to provide a smooth user interface change for UNED's professors.
- Simple panel control. aLF's panel control is difficult to manage because it has a lot of options. This ammount of options makes the course/community configuration complicated.

All these tools and their aLF implementation will be show in the following subsections.

A. The content tool

The Content tool [10] is a simple and easy tool for content creation in an educational context. It focuses on the teacher that wants to create the content of a course in a simple way with a navigation and presentation that will be easy for the student to use. This tool helps the user focus only in the content and text rather than in the presentation, order and navigation that is already done and organized.

The Content tool is fully integrated with the e-learning platform template (see Figure 2), so the navigation menu is always present for the user. This provides an easy layout focused on the didactic unit defined for an EHEA course space. The content tool has several functionalities, so the four most important are detailed here.

The integration of activities: A course in .LRN has many tools available to be linked to the content base. In order to simplify the process of linking activities, a new interface was created to guide the teacher with the process. The process of linking activities has several steps, which is why this new interface was designed to guide the user through those steps, since a multi-step process can confuse the user. This interface works mostly with javascript using visual effects for each step in order to improve usability.

The functionality of the interface, see Figure 3, is divided into two main steps with the option to go back and forth between them, when possible. The first step is selecting the activity (there is a section with the information about all the activity types), after selecting "select the activity type", the current activities of that type along with the option to create a new activity of that type are shown in an emerging section, after an existing or new activity is selected, the third sections appears with the OK option to confirm the selection and continue to the next step. If another activity type is selected after the third section is open then the third step is closed. This will force the user to select an activity from the type selected (the current selection is not lost but simply not shown until the same activity type is selected again).

The second step, see Figure 4, is to set the details of that activity, a location for the page (where the activity is going to showed) and an optional description for that activity to be displayed in the page. If the selection was an existing activity the interface will add a link to the activity selected. If however, the selection is to create a new activity, then the interface will redirect to the activity type context in order to create the new item, after which, the item is created and automatically added to the content page (but the user will remain within the new activity context in order to be able to configure the activity).

The use of these steps gives the user the option to go back one step without having to start all over again. In this interface the user always knows how long the process is going and can focus only on the current action.

Each activity is displayed inside the content of a page, where the title of that page is the same as that of the activity created (and the optional text is shown above the activity link). The link for the activity shows a message according to the type of the activity, and some validations are done before presenting the link, to be sure that the activity is published (if it is not the case, the message has no link).

Navigation issues and group template: The Content tool displays the content of every course with a template that is dynamically generated. Multiple templates for content sections are an additional option for the teachers to change the way in which the content is displayed to the users in each course; there is a set of templates available to choose.

The whole template is divided into the following parts:

- Sections: an unordered list with links to the first page of each section.
- Sub-sections: an unordered list with links to the first page of each subsection.
- Units: a combo-box with all the units available.
- Navigation: three links with an image to navigate left, right or to go to the unit's first page.
- Order section: two links with an image to move the page up or down in the list.

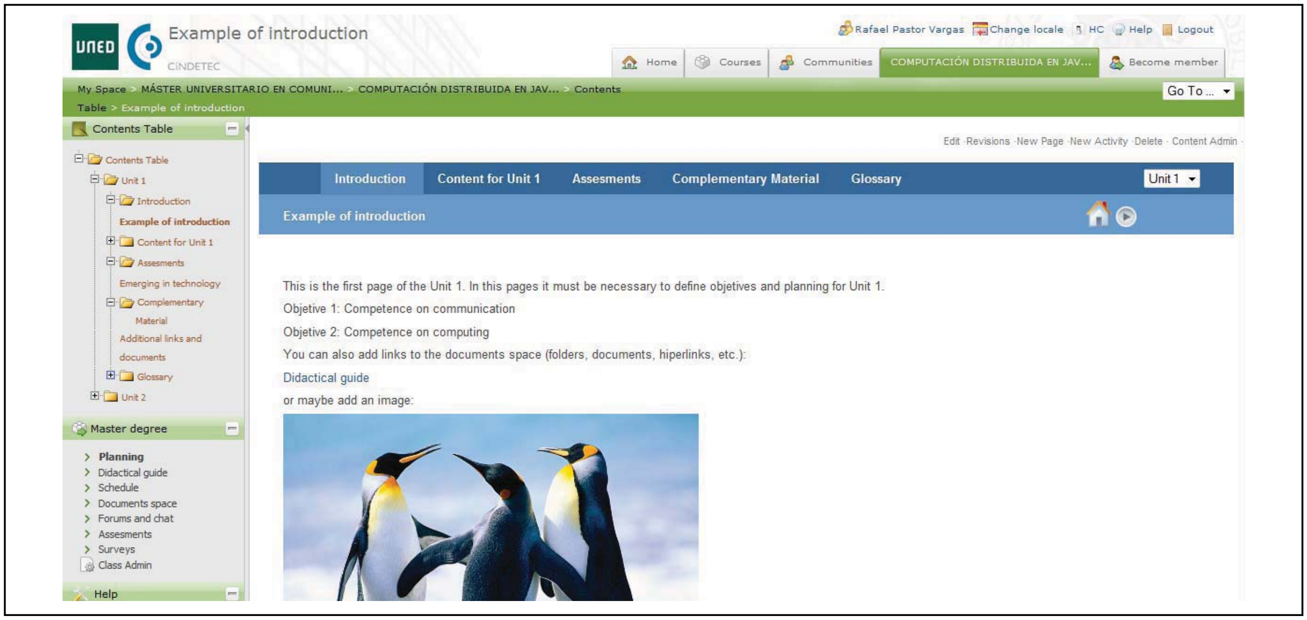

Figure 2. Content tool: Activities section of a didactic unit.

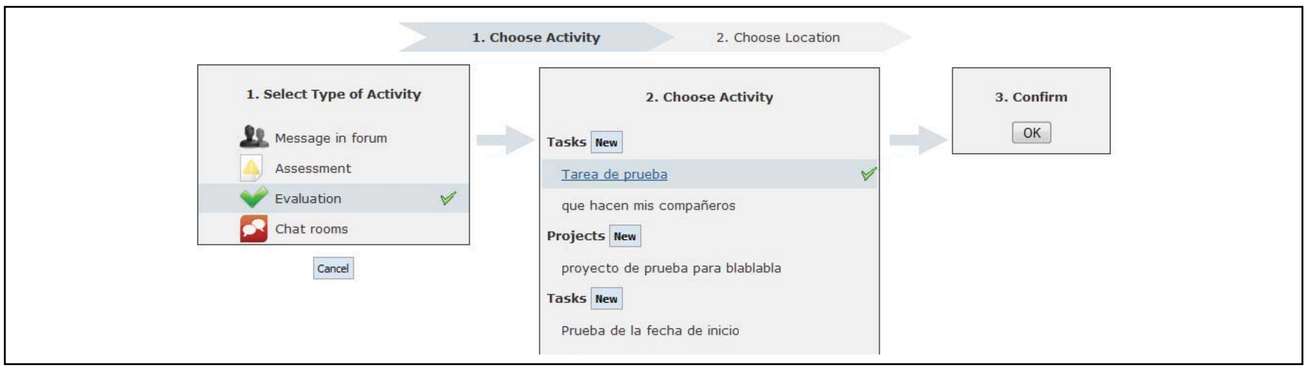

Figure 3. Step one of the linking activities process.

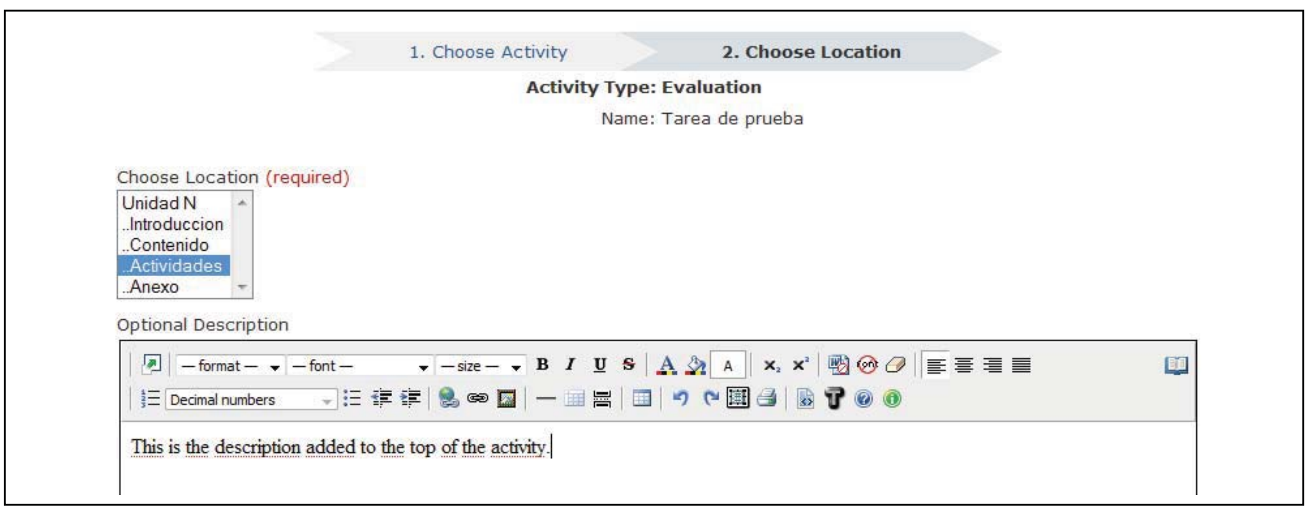

Figure 4. Step two of the linking activities process.

Content Glossary: A glossary is a very useful tool for lecturers to provide a better learning experience to the students. In every page of the content, words can be marked to have a glossary definition by an interface provided inside the rich text editor. A plug-in for the Xinha rich text editor was created to provide an interface where the terms and definitions are inserted, updated or removed. This plug-in has a main javascript file which handles the startup of the plugin and related validations, a dialog is open when the plugin is activated, the dialog has three areas, the term, the definition and the existing words. The plugin works by selecting a portion of text to add a definition to, and a dialog opens with the text selected in the term field in editable mode. A definition needs to be added for that text and all the current definitions in the course are shown in the interface, where, depending upon the selected text for the term, the definitions are ordered as being related or not related.

In every page the glossary words are links with different color and a tooltip property. If the mouse is placed over a word, the definition is shown in a popup. If the link is clicked it will take the user to the glossary page with all the terms.

In the content interface there is an entry for the glossary as an extra section in each unit. This glossary section has one page that shows all the glossary entries, and each entry has a counter that shows how many times the word is being used in all the pages. There is also an option to edit the word on a separate page and an option to delete individually or by group. This page is related to the unit where it was opened from. The navigation tree is focused on the glossary of that unit and the template shows all the sections of that unit.

Automated Copy of Content between Courses: In the content tool there is an automated option to import/export group (course/community) content pages (activities are course-based and are not exportable). The export is done by taking care of the sections/subsections related to the content and the files inside the content pages. The import is undertaken normally, following which, the import of each page is mapped to the sections/subsections, and for each activity page a new empty entry is added to the activities table. This will allow the system to treat the pages as if they were activities and link a new activity to them (the glossary word count entries are also added for the target content instance).

B. Icon based entry in a course

A WebCT user is used to have an initial view of the course based on icons in an organizational page, see Figure 5. In aLF this feature (organizational page) is not possible due to the portlet view provide as default. However, in this case a new section in the initial page of a course (joined to the planning tool which will describe later) have been added in order to add navigation icons to the most common tool provides by aLF (and WebCT): forums, study guide, content table, assessments, evaluations, glossary, tutoring (special work subgroups in UNED), news, frequently asked questions, previous exams, chat, File storage (Documents administrators) and so on. In Figure 6, it shows the default configuration on the icons navigation sections. In order to add more icons, the edition mode must be activated and then, from the select box it can be chosen from the list of available (as seen in Figure 7). Also, it is possible to move the icons using drag and drop capabilities of the section, and removed pressing the "forbidden" small icon.

Using these new features the "WebCT users" are more comfortable with the initial configuration of course, because it is similar to what they already know how to use.

Figure 5. The initial icon-based page for a WebCT course.

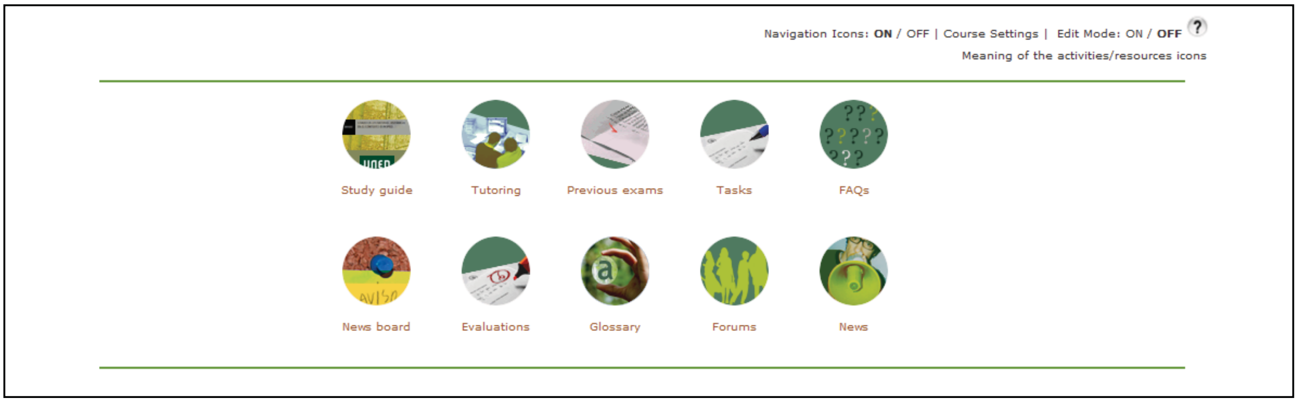

Figure 6. The initial icon-based page for an aLF course.

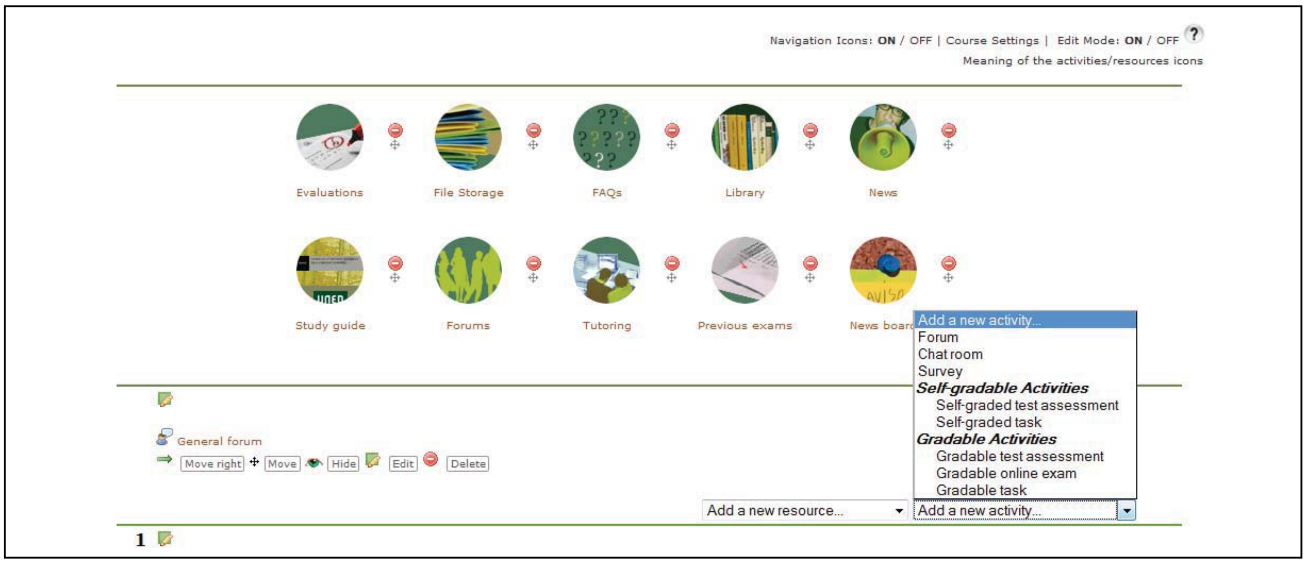

Figure 7. The tool for adding new icons to an aLF course.

C. Simple panel control

Another important feature for a lecturer is the use of a control panel in order to configure the main tools of a course, In the case of aLF, all the tools are configured in the same page (based on portlet properties for the tool) so for a WebCT user is seems complicated to find the correct portlet configuration tool and the use of scrolls and clicks are usual in order to get the correct configuration. Like WebCT provides (see Figure 8), a simplified view of the panel control was developed to have a similar interface for "WebCT users". In this case, there are four sections which provide most common administrative actions:

- User's management. Located in the upper left part of simple panel control (see Figure 9).
- Course properties. Located in the upper central part of panel. Provides features about changing of course name, description, left menu organization, etc.
- Tools configuration. Located in the upper right part of panel. Provides quick access to the configuration portlet view for the tool. Also allows the installation of new tools.
- Working subgroups list. Located in the lower left part of the panel. Provides quick access to the working subgroups and the creation of new subgroups.

VI. MOODLE BEST PRACTICES

Moodle provides an excellent tool in order to have a visual representation of didactic guide (temporal or module based) so in order to facilitate to UNED professor the definition of the course plan, a similar tool from Moodle was developed to satisfied the actual "Moodle users" from the university. In the next subsection it will be detailed.

Figure 8. The simple panel control for a WebCT course.

Figure 9. The simple panel control for an aLF course

A. The planning tool

In order to achieve the EHEA requirements, a didactic guide based on activity items (assessments, tasks, forums discussion, etc.) must be produced by teachers in order to describe the overall work that students have to do in the course. To support that, it has been created an organization and planning system by blocks where information (resources and activities) can be added by teachers from many sources and ordered in any way.

The blocks (organizational unit) [11] can have a topic or weekly format, and a summary is available for each block to describe the contents on that topic or week. For each block new and already created resources and activities can be included, so reusable activities can be defined in order to help teachers in every term (one planning, several terms).

The planning interface [10], see figure 10, becomes the Community/Course home and is organized in blocks. There are currently two formats for the blocks:

- Weekly Format: each block represents a week, the week start the day the community starts, this value is set in the Course Settings of the Blocks View. The current week is highlighted.
- Topics Format: each block represents a topic, all the activities and resources in this block are related to the topic (in this format the start date of the community is not relevant). This format lets the teacher select the current topic and highlights that topic automatically until the teachers mark it as not selected or another topic is selected, only one topic can be selected at a time.

This option is available for all communities inside the admin panel, there's a link to enable/disable this view, when the view is enabled a default empty block is created inside the community (this initial block it is always shown on top with no format), it adds the navigation bar to the master section inside that community and it automatically mounts the resources needed (evaluation, assessment, forums, content, pages, chat, etc.) on the community.

Each course has many available tools; inside each block there is an option to add a resource/activity, the supported packages are: evaluation, assessment, forums, file-storage, content, pages and chat. All the location actions are drag-n-drop based, so all the items in a block can me moved over the same block or others.

VII. Conclusions and Future Work

In this article the way in which the UNED's e-learning platform aLF, an EIS, has been developed to support virtual communities, adapted to the EHEA, has been presented. It has been argued that any e-learning platform that underlies these communities in such a fundamental way, has by its very nature to be an enterprise system, due to its robust nature, scalability, etc.

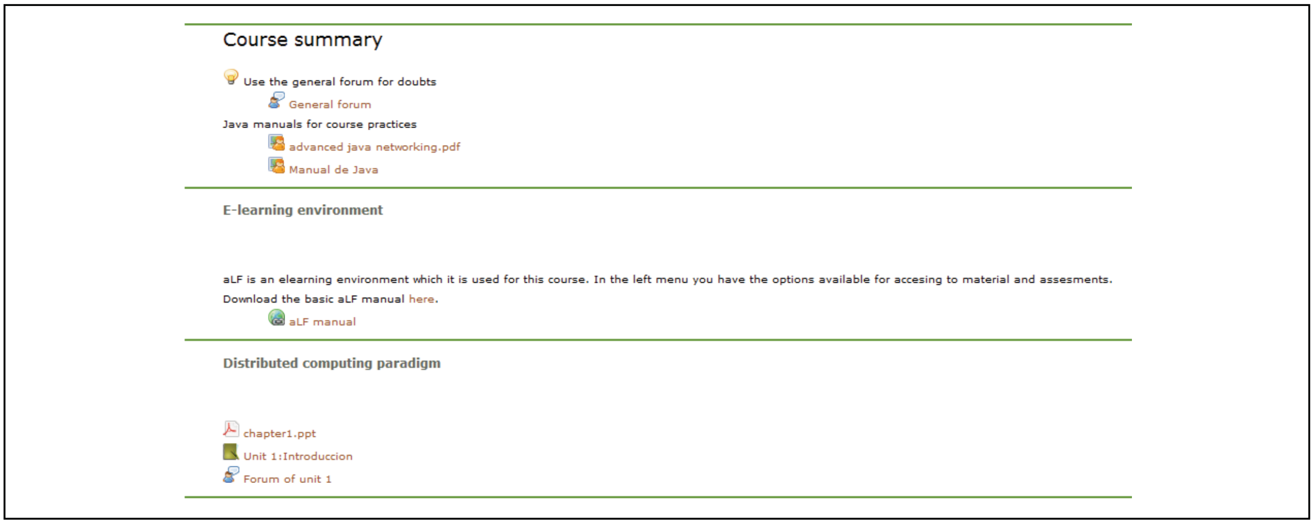

Figure 10. The planning tool based on organizational units called "blocks".

While other types of architecture (not EIS) such as the currently popular PHP e-learning platform can be made to support high student numbers (using imaginative clustering techniques), their inherent lack of scalability and other EIS characteristics, unnecessarily complicates their overall performance.

It has been noted that for the EHEA, a practical study of best practices implemented in WebCT (tools based) have been included in the development of aLF in order to minimize the transition to the new platform. Also, a planning tool like that of Moodle has been incorporated to provide a natural way for the course organization defined by the didactical guides elaborated for the EHEA. The advantage of this way of presenting a course to students is that they can see easily what work has to be done and what the sources they have at their disposition to undertake the work. The fundamentally sequential nature of each block provides a sequencing of activities for the students. For example, a student can see that initially they have to read a text, enter into a forum to discuss it, undertake a practical activity based upon it, and finally, undertake some kind of online evaluation.

As was noted at the beginning of this article, innovation is a standard ongoing activity within the UNED. As such, the development of aLF over the next few years will continue in the current direction, expanding the possibilities of online distance education, making it more ubiquitous. In basic market terms, as traditional face-to-face universities are increasing their use of virtual communities on online teaching, the UNED must extend its online teaching model to become more "face to face", in the sense of using both the synchronous and asynchronous capabilities of aLF and its tools to shorten distances and enable students to access the tools and educational resources they need to undertake their studies. As such, the future work being contemplated at present, is envisaged to focus on providing a better user experience: copying items and organizing sections, automatic show/hide functions for temporal planning, integration of didactic guides elaborated by professors from other scenarios, SCORM (Sharable Content Object Reference Model) support for the content tool (allowing users to publish and author SCORM objects) and marking up content pages for users (to provide visual tracking of content views).

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Educative use of simulators in free software for the education of the physics in the engineering programs

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Abstract - **See of the necessity that the education has of incorporating the technologies of the information and the communication TICs to the teaching-learning processes. The investigation group TICA: Technology, Investigation and science applied since for several years come developing projects of incorporation of TICs in the education.**

One of these projects is the one that today is presented in this document and whose purpose has been to identify solutions of educational software: simulation systems, virtual educational environments, educational software, among the most outstanding. But with an added value that you/they should be developed standard first floor of free software that you/they guarantee their use, modification and execution without restrictions for the final user or the institution that he/she wants to use them.

Around this topic you beginning an investigation from the year 2007, which begin with the topic of pretenders developed in free software for physics, when going developing this topic was being identified all kinds of solutions of free software, making with it that in a parallel way you began to inventory these solutions.

Today per today they have been identified near 2500 solutions of free software among pretenders, learning environments and other solutions with educational use.

And seeing this great volume you design a repository of pretenders in free software which has been denominated Open Simulates Source. This portal has as purpose to index all development of free educational software.

Keywords-component; *e-learning and learning colaboratives environment, simulation, educational software, open source educational software.*

I. Introduction

The free software has penetrated today per today all the areas of the knowledge and of the development of the society, its organization and development model has allowed him to be positioned like a true solution to the necessities and computer of the current world.

But little it is known about systems of free software for educational use, and it becomes necessary to study the evolution and the state of development of the free educational software.

Their main objective was to identify and to document the state of development of the topic in the current society and to transform this study in a repository or bank of digital resources initially conceived for pretenders that it stores the results of this study and it publishes them in the Internet by means of a place Web. And later on it includes all the types of educational software.

Defined this purpose the project gave beginning to the study on the topic and along this document the obtained results are exposed, categorizing and analyzing the low results certain variable ones.

It is presented studies by type of identified software, for type of language in that you/they were developed, for license type with the one that are distributed, for the operating system platform in that you/they are available and for the case of the physics that is the central topic for area of knowledge inside the physics.

This study takes to the reader from all over the world for projects from the local thing, projects in Colombia and going by United States, Canada, Argentina, Peru, Europe (Spain, Portugal, France, Italy, Germany, England) Asia (Japan, China, Taiwan) among the countries with identified projects. They were identified in total 50 projects of pretenders in free software, with a total of 2097 pretenders for physics. And as regards learning environments around 6, and another type of educational software to the moment d this article has been identified but of 15 projects.

Many of these projects of which an individual synthesis is made, for professors of the different universities is led, others for software communities sponsored by universities. And for the international community of free software.

1.1. Problem of Investigation

1. Do pretenders exist for educational use in the teaching-learning of the physics, developed in free software?
2. of existing these resources which the effect of the educational use of pretenders is developed in free software in the learning of the students of the class of Physics in programs of university pregrado?.

1.2. Objectives

To design, to develop and to evaluate, an on-line repository that contains material, documentation, sources and executable of simulation systems for physics laboratories developed in free software "open source" and a methodology pedagogic pilot to prove their use and implementation like educational material for pregrado courses.

Specific objectives

- To identify the simulation systems for physics laboratories developed in free software, their characteristics, functionality, technical information and the code source and the executable ones.
- To define and to design the guide of implementation of a pretender like educational material in a real course.
- To design and to develop in tools of free software the repository on-line pilot that will contain the simulation systems for physics laboratories, their documentation, sources and executable.
- To validate in a course the use of one of the pretenders and the education methodology or defined pedagogic model to implement them in a course.
- To establish the diagnosis in front of the validation of the use of the pretenders and to identify the strengths, weaknesses and opportunities of improvement that allow to use in a more efficient way this type of materials in the classroom.

1.3. Justification.

When developing this work a database it is believed with the simulation resources to support processes of teaching-learning of the physics and developed low environments of free software, which is published through Internet in order to putting it to disposition of the educational community.

On the other hand the project after developing this informative source and of resources it allows to identify a methodology for the use of these resources in order to validate and to diagnose the educational use of the same ones inside a real course of this area of the knowledge, settling down and identifying with it the strengths, weaknesses and opportunities of improvement that allow to make use in a more efficient way this type of materials in the classroom and to diagnose the disposition of the student community toward this type of resources.

Contributing with this to that you/they begin this type of works in the other areas of the knowledge, an advantage of this work is that as what is looked for it is free software, when being able to centralize the information of these solutions and the access to the same ones in a single place you can provide to the educational institutions of resources that improve the education and that they truly give solution to the social necessities that the education today per today it should satisfy.

When identifying the strengths, weaknesses and opportunities of improvement that the software pretenders get rid it contributes to the technological development of the education, besides reducing costs in the use of audiovisual resources for the educational ones, being that these resources are more economic than the use of specialized technical material of laboratory and in some cases they are gratuitous.

Also, you offers an opportunity to the educational community at all the levels to be added to the use of this innovative technology like strategy for the learning, breaking the paradigm of the use of traditional strategies.

2. IDENTIFICATION AND CLASSIFICATION OF THE SOFTWARE

The project left of two questions:

1. Does software exist (pretenders, operating systems, educational software, learning environments) for educational use in the teaching-learning of the physics, developed in free software?

2. Of existing these resources which it is the use and diffusion of the same ones inside the community.?.

With this couple of queries beginning was given to the field work that consisted on to identify software of the mentioned characteristics and to document it in order to including them in a repository or bank of pretenders.

One works during long eleven months making searches in Internet, sending letters to universities and communities of free software in order to obtain sources of information on the topic.

Parallel to this work and linking an investigating youth, technologist in systems you beginning the design and development of the on-line repository that I eat in the initial project approached single pretenders you denominates Open source he/she Simulates.

For effects of organization of the information he/she was defined a categorization system, which I include the type language in the one that you development each software, the license type with which is distributed and for the physics the category to which belongs according to the thematic one.

These variables were used to classify the results.

3. ADVANTAGES OF THE USE OF FREE SOFTWARE

The derived advantages of using solutions (operating systems and programs) based on free software they are:

Under cost. It is the first motivation for the use of the free software the cost of acquisition of the software it can already be free or of very reduced cost.

Total independence of any private sector or company. This supposes not to be bound to the market conditions imposed by software companies that sometimes show monopoly situations.

Security and privacy. When having the code source, the internal operation will be known and they will be and they will correct the possible errors, shortcomings and holes of security. At the moment Linux is immune before the immense majority of virus computer specialist that affects to the systems almost exclusively Windows.

Adaptability. The modifications and corrections of possible errors are carried out in an immediate way. This way, the applications are in continuous improvement and evolution process.

Quality. The free software, to the domain being publishes, it is being continually used and purified by a great number of developers and users of the same one that add and they demand constantly new functionalities.

Regarding the standards. The use of free software and open systems facilitate the interoperability among different organizations.

Predistribution. Any change and improvement that it is introduced in programs lower it licenses free it should be included in later versions and added to the code source. The technological development is this way continuous and dynamic.

There is not legal restriction of use. There is not limitation in the number of licenses neither of copies inside the organization like it happens with the software he/she doesn't liberate where the payment settles down in function of users' number, size of the organization, etc.

Continuity. The right of any user is guaranteed to continue the development.

Easiness. They can begin new projects based on the code of a free program or to adapt it without necessity of requesting authorization in this respect.

4. PHASES OF DEVELOPMENT OF THE INVESTIGATION

4.1. Identification phase and documentation of software resources

In this phase you looks for and I identify the solutions of educational software of type pretender for physics laboratories developed in free software in the national and international environment. This stage or phase include that to each opposing solution and that it finds been developed in the last ten years he/she was identified their characteristics, functionality, technical information, the code source and the executable ones insofar as possible, or in their defect the place Web from which you can use.

These programs were selected previous analysis of the characteristics that should complete in terms of the topic that approach, the one which you development with base in the contents that become trained in the Physical I of the pregrado programs. Those which in particular should give computer treatment of the simulation of phenomena related with the topics.

At the same time, in this phase a revision of works was made on the didactic problem of the experimental learning of the Physics [1] and [2], with object of identifying the most important pedagogic aspects that it should complete a simulation system for the educational use (theoretical contents, virtual experiences [3], tasks of development of dexterities, activities have more than enough learning [4], methodologies for development are practiced supported in pretenders [5])

4.2. design phase and development of the repository of the software resources

Previous to the design and development you selects as tool of development of the repository the PHP 5. as language programming base for those additional functions that are required, and you uses for their design Web the environment Mambo or Joomla whose use license is LPG. As agent of databases MySQL, as servant Apache Web. To configure the place web cpanel use it was made.

In this phase use of the software engineering was made to design the solution Web that would serve as repository of the pretenders and its respective documentation. I design that include the integration inside the place Web a system administration of educational contents that is MOODLE for the project, since it is free software, compatible with MySQL, PHP and Apache.

Parallel to the design you proceeded to develop the solution Web and it is necessary to begin tests of the gathered pretenders, to validate their functionality and the access to the resources that each element of the repository provides.

4.3. Phase of identification of the educational methodology and the design of implementation guides.

This phase required him to be defined the educational methodology to use to validate the educational use of physics pretenders in a real course. You proceeded to define the population of the course, the level, and the educational modality.

Selected as group pilot the course of Physical I of the Technology in Civil Works from the Ability of Studies to Distance of the UPTC.

At the same time that you identifies this educational methodology of use, you elaborates the guide of implementation of the pretender like educational material in a real course, which should help the students to carry out in a practical way a series of experiences of Physics, using the pretender selected in order to validating the strengths, weaknesses and opportunities of improvement that allow to use in a more efficient way this type of materials in the superior education the classroom [6].

Of equal he/she is formed they defined in this phase the indicators that allow to diagnose the educational use of the pretenders and the impact of the same ones in the education.

4.4 application phase

Once the educational methodology has been identified, they have been designed the implementation guide and one had available the pretenders and the system of administration of educational contents you proceeded to it incorporates these resources to the educational practice, as complementary tool in the programming of practical works of physics, in the first engineering course in programs of pregrade of superior education [7].

And you proceeds to validate the use of pretenders. You also looks for to analyze the influence of these computer applications, and of the complementary didactic materials, in the learning process that the students carry out through the laboratory experiences, evaluating the reports of the work sessions carried out with the software.

4.5. Phase of I diagnose

This final phase as its name indicates it I look for to establish the diagnosis in front of the validation of the use of the pretenders in the education and to identify the strengths, weaknesses and opportunities of improvement that allow to use in a more efficient way this type of materials in the classroom.

5. IT FOCUSES METHODOLOGICAL

It is good to specify that the methodological focus of this investigation is to describe the current situation of the topic, identifying the projects and developments of pretenders, making this investigation of descriptive type, having as primordial purpose to establish the state of development of the topic educational use of pretenders developed in free software for physics. To have presents this consideration it is fundamental to understand the results that they are presented fruit of this investigation.

As one of the objective it is to create a bank of information that identifies and present the developments of software type pretender based on free software, he/she gave place to establish the characteristics of the analysis of information in front of the topic and defining the general mark for the investigation. The characteristics that have been defined for the identification of data, their treatment and analysis are:

Software type: characteristic centered under the types of free software or the conditions of a software to be denominated free software. Taking as concept that at least fulfills one of the freedoms that have been defined in the concept of free software.

It licenses under which the software is distributed, it became necessary to identify this characteristic for this way to present in a more solid way the results.

Programming language, this characteristic looks for to settle down which languages are those that lead the development of pretenders in free software.

Platform or Operating system, this characteristic looks for to settle down in that operating systems the identified software can be used

Area of the knowledge, although the project is defined for single physics, this science has multiple areas for its development, the fundamental areas of the physics were identified and you looks for to associate each result to one of these areas.

TABLE 1. VARIABLES OF INVESTIGATION

CHARACTERISTIC	VARIABLE
Software type	Web o Applet
	Application instalable
	Operating System
	Directory
	Development Solution
	Learning Managent System
Programming language	C++
	Java
	Python
	Perl
	Swish / Flash
Platform	GNU/Linux
	UNIX
	Windows
	Mac OS
License type	GNU GPL
	Freeware
	LGPL
	Creative Commons
	Shareware
	BSD. Berkeley Software Distribution) Licences

6. ANALYSIS OF RESULTS.

For the process of documentation of the results the used instrument was a registration leaf, which you uses along the identification process and it allowed to analyze and to process the data obtained according to the necessities and objectives defined by the project.

In synthesis projects of educational software that are totally free software they are few, a good percentage of resources and projects identified in this study are partially since free software they don't fulfill the four freedoms required to be free software.

This work has allowed to establish three big categories of solutions of simulation software, of equal it forms as the physics it is a very wide science it became necessary to identify the area to which belongs each solution of identified simulation.

Finally this characterization of results taking as relating the existent types of free software and indexed in the numeral one 2 of this article and they are analyzed and they classify the results according to the types of licenses that belong to the free software.

It is important to recognize that you looks for to identify the language in which the solutions and identified projects were developed, being the language Java that of more use, followed by languages like C, C++ and Python among the most outstanding.

6.1. Identification of resources for software type.

This analysis allowed to determine the quantity and the percentage of pretenders for class of identified software, with the objective of knowing the tendency of the market in front of the software types.

TABLE 2: CLASSIFICATION PRETENDERS FOR TYPE OF SOFTWARE

Software Type	No. Projects	%	No. Objets	%
Applet (Java /Flash)	22	44,0	2069	98,7
Opetaring System	1	2,0	1	0,1
Aplication Solution	15	30,0	15	0,7
IDE	5	10,0	5	0,2
Directory	2	4,0	2	0,1
LMS	5	10,0	5	0,2
Total projects	**50**		**2097**	

Analyzing table 2 could settle down that the developments type Applet is the most common in the simulation in free software for physics. The cause of this result this in the portability of the applets, its easiness of being executed about the Internet, and the robustness for the mathematical handling of the languages used for these simulations is Java and Flash (Distributed the executable one gratuitously not the code source).

The Figure 1. Percentages of pretenders according to software type, it shows as the population of physics pretenders developed in software he/she gets rid they distribute according to the software type.

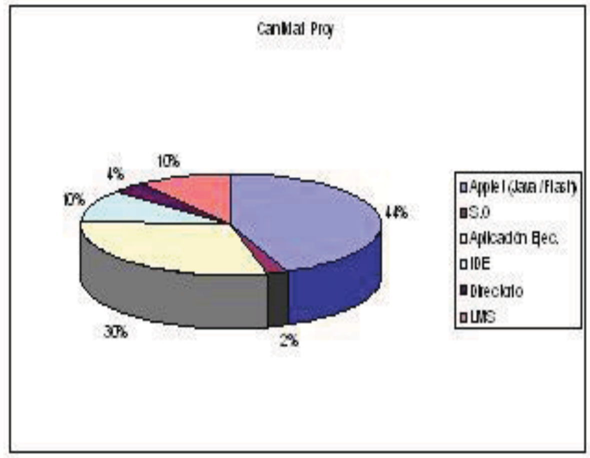

Figure 1. Percentages of pretenders according to software type

The pretenders identified type applet developed in language Java, allow to discharge the code source or binary and the execution files (. jar).

As regards applications executable type, it could settle down that they correspond in their great majority to applications to simulate graphic of high mathematical complexity.

Finally the environments of development type IDE for creation of simulations in free software is scarce but little by little they consolidate as the future of the pretenders in free software. In a numeral one later on are described with detail these solutions.

To level of directory Web or repositories of resources it was possible to identify two repositories of those more than 50 projects, these repositories are of type informative database.

And at level of operating systems of open code you identifies the operating system Ing-X that integrates the most robust and complex developments for simulation in their distribution. This project has its origins in the republic of the Argentina and it integrates more than 15 simulation solutions for multiple areas of the scientific knowledge.

6.2. Identification of resources according to the development language

Inside the investigation process and rising of the projects, to each project he/she is identified the programming language in which was developed, the object of this analysis it is to establish the tendency in programming languages for the development of pretenders and to identify the causes of their use.

TABLE 3: CLASSIFICATION PRETENDERS ACCORDING TO PROGRAMMING LANGUAGE

Programming language	No. Projects	%	No. Objets	%
Java	29	58,0	1880	89,7
Python	6	12,0	7	0,3
Flash	3	6,0	198	9,4
C++	10	20,0	10	0,5
NA	2	4,0	2	0,1
Total	**50**		**2097**	

In a conclusive way this analysis hurtles that the language Java is the more used for the development of pretenders, followed by Flash, C++ and Python. This finishes language this being proven in the system SimPy = Simulation in Python, project that has created a solution based on this language to develop pretenders in free software, see you Figure 2 Percentages of pretenders according to programming language using.

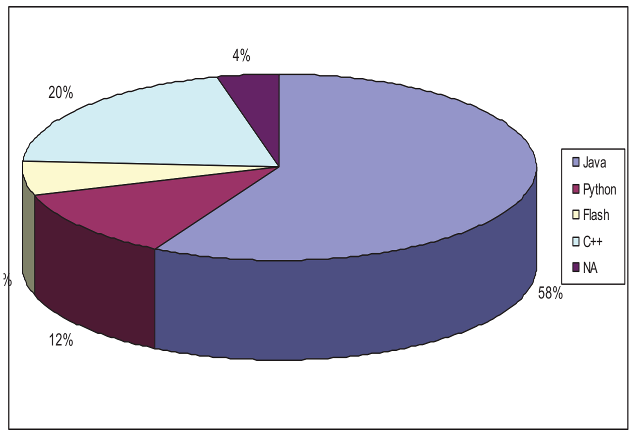

Figure 2 Percentages of pretenders according to programming language using

The reasons for those which the language Java is the more used in the development of pretenders for physics they are:

- Java is a language multiplataform that allows to develop from an independent way to the operating system the applications. Making completely portable and scalable all development in Java.
- Their packages and APIs for mathematical handling and graph in 2D AND 3D allow to integrate and to manage the complex operations and graphic that the physics requires to simulate the different events and study areas.
- Java is a language to modulate reutilizable that allows to create a development highly and then without many changes to translate it, reason that has made that in the market the pretenders type applet in java are available in multiple languages.
- On the other hand its robustness in advanced mathematical prosecution makes it very useful in the simulation topic in physics, the same as the packages of classes for handling of 2D and 3D and the graphic handling.
- On the other hand to the power to execute an applet on a navigator of Internet, he/she gives place to that their distribution and use you simple and work in practically all team of I compute.

Special case is the topic of pretenders developed in Flash, it is one of the systems of development of better graphic and very versatile prosecution when being integrated with the Internet, since these developments are guided the Web, contrary to alone Java it is possible to obtain in the great majority of the cases the executable one but not its code source, making it free in use but not in the other defined characteristics for the free software

The central difference of the developments in Java, C++ and Python in front of Flash this in that the developments under the first three languages offer the four established freedoms for the free software, while alone Flash grants the freedoms one and three, execution and distribution.

6.3. Identification of resources according to the type of distribution License

The object of including inside the characterization of the study this aspect was the one of identifying the tendency as regards licenses of the identified resources type pretender and the level of implementation of the commitments of the free software and according to the license of distribution of each resource or project.

The table 4 reflective the results of this study, when analyzing them one can do with clarity that the Freeware and knows to the software that is free as soon as I use and distribution not in permits to consent to the code source and to change it or to improve it leads for wide margin the results.

Leave with concern that in this topic the total freedoms of the free software should be approached and concerted in order to take advantage of the strengths of the development communities in the remarkable improvement of these resources.

TABLE 4: CLASSIFICATION PRETENDERS ACCORDING TO THE USO/DISTRIBUCIÓN LICENSES

License type	No. Projects	%	No. Objets	%
GPL	16	32,7	120	5,7
LGPL	1	2,0	1	0,0
BSD	2	4,1	2	0,1
Freeware	28	57,1	1867	89,0
Creative Commons	2	4,1	107	5,1
Total	**50**		**2097**	

The analysis takes to conclude that the freeware in 57.1% is the form but common of to publish and to put to disposition of the I publish a software, and the disadvantage of the same one is that they don't fulfill the four freedoms settled down by the free software, leave equal it forms that the license LPG occupies the second place with 32.7%, see you the Figure 3. Percentages of pretenders according to type license with the one that is distributed.

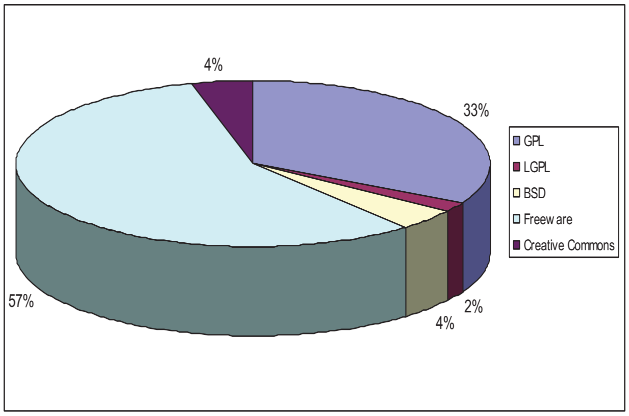

Figure 3 Percentages of pretenders according to type licenses with the one that is distributed

This takes to that thinks about the necessity to take place under oneself approach the form of transforming the freeware into license LPG to guarantee the 4 freedoms of the free software and potencilization the advantages that this development model offers.

6.4. Identification of resources according to use platform

Necessarily to identify the platform or operating system on which the pretender can be used, it is fundamental. This assures the portability between one and another operating system.

TABLE 5: CLASSIFICATION PRETENDERS ACCORDING TO THE OPERATING SYSTEMS FOR THEIR USE

Plataform	No. Projects	%	No. Objets	%
GNU/Linux	8	16,0	8	0,4
Windows	5	10,0	202	9,6
Multiplataforma	35	70,0	1885	89,9
Mac OS	2	4,0	2	0,1
Total	**50**		**2097**	

The results described in the table 5 in a conclusive way identify that the developments are in 70% multiplataform assuring with it the use of the same point in GNU/Linux, like in Windows or even Mac OS. To see Figure 4. Percentages of pretenders according to their readiness for Operating system.

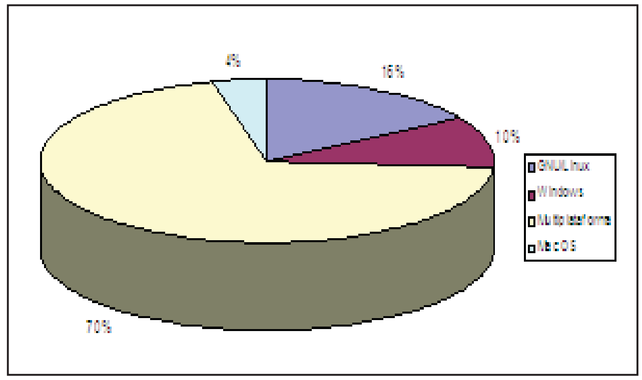

Figure 4 Percentages of pretenders according to their readiness for Operating system

This obeys to that the great majority of solutions is developed in java, and this language to be portable it allows that in a very simple way it can be used in multiple

The case of the operating systems GNUI/Linux surprises to be so low, although when analyzing it with the fact of already belonging to the category multiplataform it this being in GNU/Linux of for if.

7. CONCLUSIONS

7.1. Conclusions

In the work he/she intended to identify and to document the projects of educational software developed in free software by means of the development of an on-line repository, equally developed in free software.

It is of specifying that the results fruit of this stage of the project are satisfactory in quantity, you to identify around 2000 software solutions, each one documented and organized according to the application area.

Of this study you concludes that the educational software that you/they are hundred free percent is few hardly 42.4% in I number of identified projects and in I number of pretenders 11.4% of the total, situation that obeys the non identification of the authors with the models of licenciamiento of free software, situation that takes to conclude that in l present time the concept of free software under the principles that to this they not yet govern it they are clear for the development communities and the institutions.

Bigger effort is required on the part of the associations and foundations agents and promoters of the free software and the experts in the topic to clarify the concept.

On the other hand in their great majority these pretenders are personal initiatives and professors' of different institutions singular that moved by the desire of improving the education they have developed this type of resources and that for the necessity of the same ones they have been able to link to these initiatives to other colleagues.

It is required to lead in a more organized way and with approaches of quality of educational software and of the dynamics of systems this type of projects so that inside a community of developers a model of development of free educational software consolidates.

From the educational point of view several projects were identified that are very solid in the methodological and pedagogic that can be the courses to consolidate the educational use of pretenders inside the society.

7.2. Future works

Identified those more than 2000 software solutions developed in free software a very important future work would be given by the validation in educational terms of these resources and under the approaches of quality of the educational software. Investigation that would allow to have better elements when making use of these resources to the educational and educational organizations.

Of another part with the existence of integrated environments of development of free software should be carried out the analysis and study that it takes to define the methodology for the development of pretenders and free software using these systems and with their respective validation processes from the pedagogic thing, the instructional design and the theories of the learning that sustain the quality of these systems.

He/she thinks about the possibility to investigate this same topic enlarging it to other areas of the knowledge, since when developing this project it was possible to glimpse that there are pretenders for many other areas, but that of equal it forms they could be identified and by means of a repository to place them within reach of the community.

A later project to this he/she should take these pretenders and to validate them from approaches that measure the learning and their impact in the processes of development of knowledge.

8. GRATEFULNESS

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Session 03G Area 3: New Frameworks for Engineering Education

Engineering societies as a vehicle tool for engineering students.

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IEEE Student Branch UNED (Spain)

Knowledge, skills, and competences -- Descriptors for Engineering Education

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Implementation of An Engineering Educator Graduation Program for the formation of New Skilled Engineering Teachers

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enginy@eps: Motivating the Engineering Courses

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Engineering Societies as a vehicle tool for engineering students

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***Abstract*—This paper describes the importance of Engineering Societies inside the educational environment, focusing on the new learning models that appear in the student branches. This model involves pedagogical methods differents than the more formal ones used in the classrooms. They are based on more informal approaches where learners are the real center of the process and teachers appear just as tutors or learning drivers, providing the required material and support to learners. The paper describes the successful experience of a Student Branch in a University for Distance Education, overcoming the traditional collaboration and interaction lacks that these kinds of institutions own due to its inner organization and learning methodology.**

Keywords: Engineering Societies; Student Branch; blended learning; active learning.

I. INTRODUCTION

Engineering societies play an important role inside the university environment, due to they can become a vehicle between university and industry, helping learners to acquire different knowledge than the provided by the formal education. This knowledge could be an important added-value for students when they arrive to work market because they will own more knowledge, experiences and capabilities than the other applicants [1] [2] [3]. These new skills will be the key for their future professional development.

In addition, active participation on these Societies can help learners to improve their self-learning abilities, because they must learn by themselves many technical concepts to put them into practice [4] [5] [6]. They also improve their social skills, such as leadership; organization of projects, talks, workshops, publications, etc; and work scheduling (for themselves and for the group). On the other hand, other advantages are the improvement of their own technical knowledge in the areas where they are interested in (they have access to the latest information about technology), social networking and knowledge about other cultures (with other students or professionals interested in the same areas all over the world).

But in these groups usually learning does not happen spontaneously. Some kind of impulse is required to encourage students to participate in an active way. Usually, it happens through the participation on contests (e.g. robotics, programming, networks, etc) or through interesting projects to achieve a particular goal. Other incentives for the engagement could be attendance to technical talks, workshops or publication of papers on journals or conferences. Enjoy, learning and success are guaranteed when a student is suitably motivated.

A very good example of the successful implantation of these societies at Universities is the IEEE Student Branch of UNED (Spanish University for Distance Education). This group has overcome the problems of having the members spread all over the country [7]. The paper describes the distributed organization of this group and the use of virtual tools to support the communication and collaboration among group members.

Engineering Societies arise as a very good vehicle to complement the formal education, providing at the same time experience in real projects that will be very useful in the integration within the work market.

II. POWER AND POTENTIAL OF ENGINEERING SOCIETIES

It is a fact that in order to teach anything, you firstly must know something about it. Engineering Societies had been working in their knowledge field during many years. That is why they are the source of many answers to learn and subsequently to teach. Usually, students only connect with Engineering Societies when they finish their degree. This situation generates an important gap between learnt theory in their degree and real life. The solution would be to keep in touch students and Engineering Societies during academic time. This new approach will give students the possibility to use their recent knowledge gained in their degree, in real life without gapping. This possibility promotes students to pay more attention in their studies. It means that the acquired knowledge will be more useful and enjoyable in their careers and, most important, in their degree years.

In fact, when a student finishes the degree, Engineering Societies will be the link between academic and real life, and will be the new way to continue self-training. The adaptability that Engineering Societies have is a key feature that new degrees should acquire to develop a professional success. In this point, the IEEE-UNED Student Branch thinks that this feedback after degree must start during academic formation. The IEEE-UNED Student Branch has been working in that line for many years, trying to look for the mechanism to obtain the most of this relationship during academic years.

In our case, we are working with the IEEE (Institute of Electrical and Electronics Engineers) organization. IEEE has several levels for professionals and students to develop before, during and after his/her academic and professional career. We are using the called IEEE Student Branches.

An IEEE Student Branch is an association for students in Technical degrees (Physics, Engineering, Maths, etc...). Its labour reflects clearly how it must articulate the relationship between academic and real life.

In the situation of the UNED, Engineering Societies promote students to develop their own projects. On the other hand, Engineering Societies give them support and advising. The most important part in this relationship is the freedom of students to manage and develop their own objectives. That is the reason why motivation has a special role. The only way to give students responsibilities and maturity in their actions is give them the opportunity to make mistakes and learn from them, at the same time that they solve them. That must be the worker's behaviour in real life.

To train students you must give them skills, but these ones not only must be academic in their area of study, but skills in other areas. These new areas of work may have interest to teach them about management, organization, working in group, collaboration activities, language skills, commercial skills, etc. This Engineering Societies have the possibility to offer those skills to the students because they own as members enterprises; mentors; academic professionals; engineering professionals; public and private employers; business partners; or big and small enterprises. Definitely, they have the most representative roles that students will have to face when finish their degree.

Currently, the IEEE-UNED Student Branch has four important ways to connect Engineering Societies and students:

1. Through Contests. One of the usually ways to motivate, develop and check students' skills is with contests. Most of engineering degrees are related with experimentation and mechanical experiences. This is a good excuse to make a contest. The key is showing the students that academic theory is useful to provide answers to real life. Activities like Robotic Contests, Olympics Maths games, Innovation Contests, and others similar activities work because students learn the practice of their studies and develop competition and cooperative skills. A very good example of this in the IEEE is the IEEE Xtreme programming contest. In this competition, students in all IEEE Students' Branches around the world will compete to show that their students are the best programmers. In this challenge, a team of students will have to solve several problems in 24 hours. It is obvious that a contest like this will teach students a real experience in solving problems with a deadline, work in group, work under pressure, etc. Of course, the winners will get fame and maybe some new opportunities will appear for them to get their dream's job.
2. Through Formation. We can talk about two formation ways:
   a. Academic Formation: With several activities like technical workshops, language workshops or attendance to technical conferences. It helps to develop academic skills.
   b. Professional Formation: With Management Workshops, visits to enterprises, financial and marketing workshops. It helps to develop professional and personality skills.
3. Through Labour Market. Put real life in front of students is the most important thing. And real life means to talk about the success, but even more important is to talk about the failure. Students must know enterprises into technical studies and learn about that, visit them and learn their growth process and fall. If students know that real life can be dangerous, they will be more motivated to think about their skills and lack of them that they have. Academic world is a quiet environment for the students, only exams time generates a few of stress in that environment. Usually, they have only one deadline: the day before the exam. Real world is an aggressive environment with daily deadlines, study, work, or family, with more stress and less time to react, usually without second opportunities. The only way to train real life is living it, and the only chance to students to experiment real life is through the important experience of Engineering Societies about it, its advices and by using its skills. Moreover, the societies have experience in project failures, and it is very important to teach students about the mistakes of the past, as it is the best way to avoid having the same mistake over and over again in the future.
4. Personal Issues. It is important to motivate students with Engineering Societies and vice versa. But there is another factor: the personal one, which belongs to other scopes besides the professional one. Engineering Societies help students to work together, helping themselves to study better and so making their work also better. At the IEEE-UNED Student Branch, this is a very important factor. Students have not direct contact with teachers, so they have to study by themselves and help (and be helped) by other colleagues. That is one of the reasons why the personal inter-relationship can be very important and make to grow up these Societies.

Another very important factor for the Engineering Societies is that they give the opportunity of networking. In today's world, there is a lot of competition to get a job. One of the best ways to help students to be successful in obtaining their dream's job, is having contacts everywhere. For sure, all readers going to know at least one case of a person that got a job because of a friend, teacher, parent, etc. Engineering Societies bring the possibilities of put in contact all the persons interested in the same engineering field. For example, according with the experience in the IEEE-UNED Student Branch, through the robotics workshops, all students with interest in robotics have been in contact, resolving problems together, developing projects or even just having fun in general meetings. Of course, inside of this contact groups there are professors and professionals. Therefore, through the participation in the Society, professionals will meet students that can be a good future bet for their company. On the other hand, students will meet professionals that can give them a job in the future.

This kind of socialising can be seen in all the IEEE structure because of its division in professional Chapters and Societies: communications, signal processing, information theory, broadcast technology, etc. All engineers with a common interest will be put in contact easily through each particular society. In the IEEE-UNED Student Branch we have students with interest in several technologies. In this way, if they get enough people with interest in the same Society, they will be able to create a Chapter of the Society. The advantage of this is getting funds from the society to develop projects, the possibility to do contacts with engineers with interest in the same field and be informed of the new related technologies.

On the other hand, Engineering Societies are very important to achieve sponsors to student projects, because the enterprises get publicity and have the opportunity to evaluate at the students in real time. We don't forget that more of those students would be potential employees in the future and they would be trained in the last technology and resources of sponsor enterprises. At the same time, students know the enterprises around their academic specialities and have the chance to keep in contact with them before, during and after project finish. Usually, during academic years, students have to study old systems and technical resources, mostly obsoletes. Introducing enterprise vision in a real project, students can use new resources, even experimental resources, and keep in their minds the necessity of stay update in their studies and in their work if they want to be competitive.

An important aspect of this relationship is that Engineering Societies can act like a tool to show to the Bachelor's School the way to adequate academic formation and real work. This mechanism could be seen in the collaboration of both sides; Schools and Enterprises; through the Engineering Societies in the elaboration and preparation of contents of academic studies. Joint projects and periodical activities would be the better way to keep and enrich this contact. These activities could offer to the enterprises a real vision of the weaknesses and the strengths of the students to solve and potential those weaknesses to get the best of them.

Finally, we can think of this relationship is a cost or an investment for Engineering Societies. We must not forget that Engineering Societies are formed by enterprises and institutions. They work with money and they plan their investments, actions and efforts to achieve the success and challenges. As we said, these activities and efforts focused on students are, without doubt, an investment. There are many reasons: new trained professionals, new future and motivated employees, important marketing activities, better knowledge about employee market, and a way to show the Engineering Societies, and their member enterprises, the important social implications they provide to the society.

III. MOTIVATION IS THE KEY

It is difficult to keep the attention of students in an academic class, but it is easy keep the attention of everyone in a game or in an enjoyable activity. This objective is the path of a teacher. If he/she want a thoughtful audience must turn his/her class in an interesting moment for feedback, interchange of opinions, look for answers, and above all, set out questions. What can we do about motivation? The answer is simple; student must be involved with the lesson. One of the ways to accomplish this goal is to transform the student into a teacher. In several workshops the IEEE-UNED Student Branch have worked with students with knowledge about robotics, electronics, web development, etc. in this cases, student has been invited to participate in the class like a teacher, he/she have to explain the others students the lesson of the day or, in some cases, he/she can suggest the lesson of that day. This activity reinforces the attention of students and increases their self-esteem.

It is true that this kind of class requires more flexibility and participation from teachers, but in a few time this effort is rewarded with the attention of students.

With the attention focused, we can look for motivation. Everyone has skills but not everybody discover them. In this moment, teacher has the opportunity to show at students how other people works day by day in different; technical areas in our case; exploiting their capacities. Using Engineering Societies like a model, it is easy to show students how they can work in group, and the first thing they must learn is that in the group everyone is important and everyone has a function. What is the function? That is the first step to take the student at a motivation attitude. In our workshops this is the moment when the teacher hands over the word to every student and every of them have to show the others his/her abilities and how they can help to the group to achieve the objective.

As you can see in this moment, IEEE-UNED Student Branch is changing the workshop into a meeting, it have achieved to dissolve the figure of the teacher; although he/she stays there monitoring and supervising every step; and students are working together imitating how it works an associated group.

This is the moment to purpose a project or a challenge, because we have captured the attention. Students are motivated and that is the moment to prove if they can work like a team and have a success or if they can work like a team and to bear a failure.

We can say that this behaviour is the one of Professional Societies. Their members are working together to achieve one objective and if they fail, the Society give them support to accept the failure or reduce its negative consequences, if it is possible. In fact, activities like contests, or similar, are looking for foster this aptitudes in the students.

Motivation is linked with social activities too, like contest or similar. On this way motivation could be an economic price, an opportunity to work in a real project of one of the sponsor enterprises, technical resources (e.g. tools, information or publications), an academic publication with national or international importance, etc. Engineering Societies have the possibilities and contacts to get these prices. As we said, Engineering Societies act like a connection between different enterprises and institutions, they know potential clients and suppliers, and everyone could be future sponsors in a student activity, everyone could need publicity, employees or, even, new future clients or suppliers, because students today could be successful professionals or enterprising tomorrow.

In Spanish University for Distance Education IEEE Branch, we have other motivations to study. Usually, we join this university because we are workers and we want to grow up in our life and jobs. One of the motivations is that we cannot see the teacher neither all the students can receive face-to-face classes. So, one of the motivations could be to think that nothing can "stop" us in our chance to study, neither our families, neither our works, etc. Then, we can afford the study of the subjects with the idea of passing the exam, that really it is more than that, it is passing many issues of the life itself. Therefore, motivation is very important for that reasons.

IV. ACTIVITIES

According with our experience, main activities can be split in two groups:

1. Collaboration activities are looking for reinforce group figure in the real life environment. Projects are the most representative figure in this way. In the engineering field, we can find projects in public or private enterprises (NASA, ESA, Telecommunication Societies, Aeronautic Societies, Automation Societies, etc...) and usually these enterprises have representation in Engineering Societies so, when it is called a project for students it is a good moment to prove if they are ready to work in group, to assume responsibilities, and to involve in a common objective. If students have success or not, is not so important than they can think, the important is working together and learn for the next project. In fact, the most important thing is that regardless whether there is economic award or not, students have been motivated during the project and they have developed new skills during this time.
2. Individual activities are necessary because there is a leader in each group, or a project manager to take difficult decisions or assume failures if would be needed, but everyone have, in any moment of his/her life, to take decisions, to have success or to make mistakes. In this moment individual contests, or similar, show to the students their possibilities, their real skills and teach them how to acquire other tools to face the professional world.

To develop both groups the Engineering Societies give support, help and advice to call activities in this way into the student branches. Any of them would be:

- Technical Workshops: About students' career, like robotics, programming, wireless, etc. To develop their technical skills and complement theoretical knowledge.
- Non technical Workshops: About management, leadership, marketing, organization, e-commerce, e-learning, etc, offering tools to complete student formation.
- Nationals and internationals congresses; conferences and other meetings; travels and visits to different places (NASA or INTA installations, private or public companies, etc.). There, students can meet other students and interchange experiences; or with professionals, generating an interesting feedback for their learning.
- Contests, projects, or championships for the students to motivate, award and recognize the students' efforts every year.

IEEE-UNED Student Branch organise some similar activities in different Associate Centres of UNED in Spain and we can say that results had been very positive.

Taking a look over the activities, we can find out some of the most successful activities of IEEE-UNED Student Branch:

- Robotic workshops: Initially, professors of UNED with the collaboration of some students did an initial workshop. Through it, students had the opportunity of learning with a real robot the basics of robotics and automation. This initial workshop let students organize their own workshops, until the point that now every year IEEE-UNED Student Branch has one or two workshops about robotics in several centres. Now, those students can be proud of having reached a third position in a national competition of robotics. The role of IEEE was essential to reach the success of this activity because part of the sensors used by the students was bought with IEEE funds. Currently, some students are thinking in doing a Chapter of the Robotics and Automation Society, to have access to the latest information in the robotics technology and even more funds to get new sensors or develop new activities to continue going into depth in their knowledge.
- SSETI SWARM project: Students of IEEE-UNED Student Branch got the opportunity of participating actively in this project to develop a Cubesat. All the participants have gained very important skills for their future career (work under a deadline, management, communication skills, and work in group).
- National and international student congresses: IEEE puts the funds and organizes multiple conferences for students. In Spain, we can emphasize the CNR (National Branch Congress in its acronym in Spanish), which every year concentrates students from all Spanish Student Branches. It let them meet students with the same areas of interest of the whole country, share experiences and ideas, learn about the activities of other branches, start projects and extend one's

social network. At an International level we can find the SBC (Student Branch Congress) which meets students of the entire IEEE region 8 (Europe, Middle East and Africa). This is an amazing congress for students because they can socialize with students of several countries, know about the engineering concerns in each country and even try to start student international projects. All of this without forgetting what they can learn in the congress about leadership, career development, communication skills, etc.

- IEEE congresses and paper presentations: IEEE organizes plenty of conferences with special offers to students. In those congresses, students have the opportunity of learning about the latest technology in different topics.
- IEEE online webinars: IEEE offers online seminars and students can attend to them and learn from experts the news about the engineering technologies.

Obviously, this is an ideal stage for the companies that look for new qualified employees.

V. THE IMPORTANCE OF FEEDBACK

One thing to remember in this kind of associations is the fact that their development is based on volunteering. That means that every participant in the Society is collaborating by free, or even they have to pay to belong to the Society. For that reason, the Society has the obligation to offer compensation to every volunteer collaborating in the activities.

Here there are two profiles which the Society has to cover offering a feedback.

In first place, we can find students. They want to learn, they are looking for developing a great career and they want to know how the real life works. After reading that, the reader can think that is all done: they have all they want and need in the Engineering Society. Unfortunately, it is not so easy.

The experience in IEEE Student Branch of UNED tells us that almost all activities have to be organized by students. That means they use their free time to pursue the success of the activity after a tiring day at the university or, if we speak in the concrete case of UNED, after a hard day of work, study and attend the family responsibilities. How can we achieve the involvement of the students in their free time? Engineering Societies have to show them that they are not going to get only some extra knowledge about the topic of the activity. Recruiters are looking for people who have good communication, leadership and organization skills, who are capable to work under a pressure of a deadline and with capacity of working in group. Students have to see how they can develop those skills through the organization of the activities; they need to know that they are using their time to gain abilities that going to put them in advantage in a job interview in front of people who have not participated in any society. Moreover, because of pure practical feature in the activities done in Societies, all students will get a real vision about all the theoretical studies they have done.

Following this way, we are going to have two kinds of students inside of the society. On one hand, it is possible to see the "active" student, who is the responsible of the development in the activity. This person will learn new skills that cannot be learnt inside of a classroom, such as previously described, and he/she will need use one's free time. In addition, the initiative showed by the student, will put him in contact with professors in a closer way, having the opportunity of getting involved in their projects and therefore, and learning advance knowledge in the topic of those projects.

On the other side, we find the "passive" student. This will be the person who belongs to the Society only for the advantages of being able to attend to the courses and activities done within the Society. Of course, the pupils will be able to participate with both roles depending on the activity.

In second place, the professor/tutor profile. We have to think that professors in Universities have their own projects, obligations and duties. In most of the cases, the Societies have limited economic resources, so they cannot offer money to professors to help in the activities. For that reason, it is necessary to find a way to attract tutors in the activities that are developed within the Society. Professors have their career done, it is improbably for them to learn something interesting in these extra-activities and almost for sure, they may have a complete CV that does not need more elaboration. So, how can we do it? Maybe a professor has their career achieved, but there is something that whatever engineer wants to get within their career: reputation and recognition.

IEEE, as engineering society, let people grow up inside of the organization. To get a promotion, they must do something to contribute with the society and with the engineering community. As professors, they can collaborate in create a new student branch inside of IEEE and get more members for the society. Moreover, IEEE offers to the students the possibility of giving awards to the mentors that are helping them. Through an active collaboration as tutor, students will give them that recognition. This fact will help the professor to have more reputation inside the society.

Finally, they will be able to see in first hand, students that are more brilliant putting in practice the skills learnt in the subjects, that show more initiative and that have good ideas to develop projects. This will let to professors, selects students that can help them with their own projects.

Figure 1 represents a summary of the feedback given for the Engineering Societies:

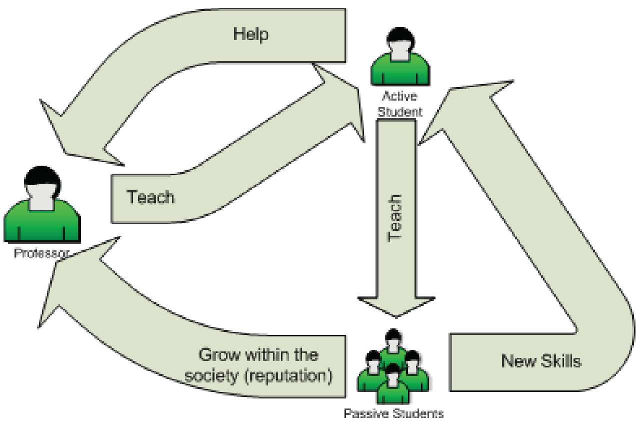

Figure 1. Feedback work flow.

The following are the roles involved in this process:

- Active student: He/she will develop new skills with the organization of the activities (communication, leadership, organization, work in group, etc). He/she will learn advance knowledge collaborating directly with the professor, and will be able to transmit this new knowledge to other students.
- Student Group (passive students): He/she will learn knowledge from the active student and will let the active student to acquire new skills. They will recognise the help of the mentor.
- Professor: He/she will be able to select the most appropriate students to help him in his/her projects. He/she will help in the activities done in the society, and will grow up in the society and get reputation and recognition.

VI. FROM THEORY TO PRACTICE: IEEE STUDENT BRANCH OF UNED

Since 2004 we work together in IEEE Student Branch UNED. The first steps were very difficult because UNED is a distributed geographical and physically University. At the beginning, our objective was to develop several work teams in different Associate Centres of the UNED in Spanish geographic: Madrid, A Coruna (Galicia), Terrassa (Catalonia) (Figure 2). Today, IEEE-UNED Student Branch can brag about have achieved this objective and go far away.

The key was the strength collaboration with IEEE organization and the hard work with students interested in learn more about engineering and cooperation like a work team.

Figure 2. Scheme of distribution of the activities in IEEE Student Brach UNED: an example of collaboration between IEEE (Engineering Societies) and UNED (University).

Why IEEE? Many reasons can answer this question:

- It is an international organization: This is an important point because most international and national enterprises belong to IEEE and this is an advantage for students that find closer new opportunities of work.
- It is the bigger Engineering Society in the world with more than 350.000 engineers belonging to it in 150 countries.
- The academic teacher of IEEE-UNED Student Branch and counsellor knows and belong to it. It was very easy for students of UNED to link with IEEE for the experience of one of its members. Students knew the possibilities and benefits of this Engineering Society and they knew the mechanism to belong to it.
- IEEE manages most of the international standards in Engineering. Belonging to it makes easier to know the latest researches and technological advances in many fields that engineering students have to know. This is very useful in order to have the best and upgraded formation; and information; in this fields. The only fact of being member gives you the access to IEEE Spectrum Magazine, The Institute Newsletter, IEEE Potentials Magazine and more. It will let members be informed about all the new technologies and save time in future as one does not have to "reinvent-the-wheel". We have to think that these IEEE publications are not available on Google for free, so the membership of IEEE can save time in research.
- Long years of life. IEEE is 125 years old, years of investigation, knowledge, standards, linked market and technology, linked enterprises and Academic institutions, linked governments and engineering.

Definitely: a lot of experience to absorb and to use for students.

- And networking. A lot of possibly contacts, to learn, enjoy, participate in contests, and even to teach or to work. An important and recognized organization like IEEE has the possibilities that student wants.
- IEEE offers multiple advantages for students to develop their career, like scholarships, the continuing education partners program or the IEEE job Site, which let look for jobs and career opportunities.
- IEEE is a very successful institution with a worth recognition for all the companies. IEEE offers the possibility of getting professional certifications to demonstrate your professional abilities. By gaining these certifications, you will enhance your CV with an international certificate with credit in all the companies.

On the other hand, by using several of the resources of IEEE, we have been able to call and organize several projects during recent years. For example, in 2008/2009 term these have been some of our activities and projects:

1. Annual Workshops: We are working in workshops about different areas in A Coruna and Terrassa Associated Centres.
    - Robotic Workshops: Today, IEEE-UNED Student Brach have a lot of activities related to robotics like coordination of contest, conferences about it, "webinars" (on-line seminars), etc... Student Branch is looking for more interaction with enterprises in this way, to give to students more opportunities in employee market in their future.
    - Wi-Fi Workshops.
    - PIC's Programming Workshops.
    - Joomla Web developed Workshops.
2. International Projects: Working like a team let members of IEEE-UNED Student Branch to take part in international projects. At this moment, students are working in two of them:
    - SSETI Swarm Project: In collaboration with other international universities some students are working since august 2008 in a space project where their work is designing and building a communications system to keep in touch a satellite with ground on Earth and vice versa.
    - Proposal to REXUS/BEXUS project from E.S.A. (European Space Agency): In this moment, IEEE-UNED Student Branch has a team working in the proposal to send to ESA in a space project for European students.
3. Informal meetings to explain our activities and present new projects: These informal meetings are executed during different months along the year in the Associate Centres of UNED. We explain our activities, offer our infrastructure to other students and talk with them about IEEE and other Engineering contests and activities in and out of our country.
4. International meetings with other students and with Engineering Societies to link students and enterprises: IEEE-UNED Student Branch has been enjoying in last meetings in Lisbon ISBC, London SBC, etc. Also, Student Branch has coordinated a Robotic International Contest in April 2009. In fact, the success of this events, are encouraging us to organize the next Spanish National Student Branch Congress with participation of international students and collaboration of Portuguese students branches.
5. Web resources: to keep in touch every moment we need to use tools like MSN, Skype, Google docs, Internet is our better tool to link different cities in our country and develop projects together despite the distance among us. Obviously, we have meetings when we have the opportunity, but sometimes distance makes it very difficult. In these cases, we use Internet tools to solve our technical problems, coordinate our projects, and organize our workshops. Discipline, a good use of time and organization are the keys to make this methodology works.

Definitely, contacts, links, enjoy, but also earning, formation and work. Engineering Societies may work like the nexus between real and academic life, they can be the support of enjoying and funny during academic years, and they can make that students' formation will be complete. Not only academic knowledge builds good professionals, but relationships, market knowledge, organization, etc. All these characteristics and skills will make of student a better professional in the future.

VII. Conclusions

At first, we can think that Engineering Societies and students are not related, but we are wrong. The relationship is very important, because both concepts have a big interdependence and they are complementary. Engineering Societies are useful to students, because they contribute with theory of the practice given in engineering degrees.

Definitely, two ways but only one objective, growing like highly-trained students is the key to allow Engineering Societies have highly-trained professionals. Often when students finish their academic career the labour market has to contract and train them again. That supposes money, time, and a considerable effort for the enterprise and the student. If we keep in touch student and Engineering Societies, during academic years, we are reducing that costs and we are showing at both sides to use the potential of academic and enterprise philosophy, the basic formation in Engineering and the specialization in different markets and business engineering fields. In fact, what we are doing is forming realist professionals and taking advantage of their university formation to put into real engineering practice. Through the use of Engineering Societies, students, besides additional study motivation, also gain experience in scientific experimental design, project team work and management which are important knowledge for their future careers. Moreover, if Societies help students to grow up in their careers and form new professionals, they will keep alive their own future, because are these students who have to be part of the Engineering Societies in the future.

We must think that students today will be the new professionals tomorrow, and they have the responsibility of improving life, environment, technology and security of our future.

If students have the support of Engineering Societies they can know their weakness and solve them. Then they can fight against the new challenges of the real world. On the other hand, Engineering Societies can know the abilities of future employees or professionals and show them how work like a team, how engineering enterprises actually work, and how use their knowledge to boost the enterprises and institutions they will work for.

Our Student Branch is an example of this rich exchange between students and Engineering Societies, between academic and professional life, it is, between theory and practise. All this effort will be beneficial for the two sides: students will be better professionals and will have more skills to solve problems in their future work. On the other hand, Engineering Societies will have new active members with new professional contacts that will look for new technological challenges and will enrich the knowledge of Engineering Societies, reinforcing its role in the society.

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Knowledge, Skills, and Competences

Descriptors for Engineering Education

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Abstract— **Since the European Parliament has given an according recommendation, qualifications are to be described in terms of knowledge, skills, and competences. In this paper, these terms are redefined in a way that they are put into relation to learning-models, thus making possible to describe qualifications in engineering education in a more rigorous and verifiable way.**

Keywords- education;qualifications frameworks; assessment

I. INTRODUCTION

In December 2004, the Ministers of 32 European countries, responsible for vocational education and training, decided to create a European Qualifications Framework (EQF). The European Commission presented a proposal for this framework, which in a revised version was confirmed in 2008 by the European Parliament [1] with the explicit statement that it might be applicable not only to vocational education and training, but also to general and higher education.

In the corresponding documents, it is requested that the different levels of qualifications be described in terms of knowledge, skills, and competences, which in turn requires that the latter might be assessed on a largely objective basis. That would not be possible without a clear definition of these terms.

This is the point where first difficulties arise, since the different branches of science use these terms in different contexts and with different meanings. However, as largely objective comparison of learning outcomes is the main aim, science-based definitions only will be considered in this paper. Hermeneutics will not be discussed here, though these might give rise to interesting disputations.

Another restriction suggests itself: Since learning-outcomes are to be assessed, terms should be defined with strong relation to accepted learning theories.

Therefore, a short introduction to some essentials of a learning model will be presented that gives insight into the different steps of learning. With respect to this model, different definitions of terms will be discussed, ending up in a suggestion for their re-definition. As a consequence, some methods of assessing knowledge, skills and competences will be considered.

II. FIVE STEPS OF A LEARNING CYCLE

It is meanwhile widely accepted that learning is a cyclic process (see for instance [2] - [4]). Following [5], the steps of a learning cycle are given as in Fig. 1.

The different steps of learning in a cycle are:

1. Get to know facts

   This is the most basic learning step. It serves to memorize basic pieces of information. This type of retrievable information is called *factual knowledge* in Bloom's revised taxonomy of learning [6].

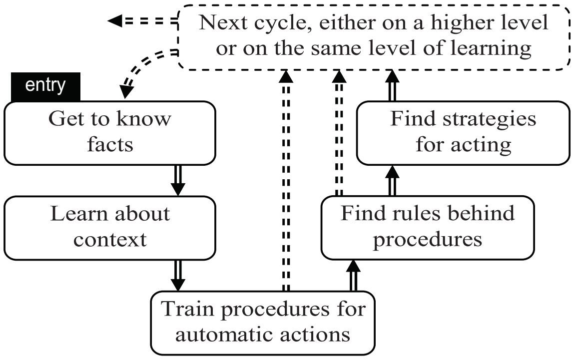

Figure 1. Diagram of a learning cycle on a specific level of learning (from [5] with permission by IEEE)

2. Learn about context

   Knowledge on facts must be linked to other pieces of information in a context. Facts could have completely different meanings in different contexts.
   This might be demonstrated by the example of memorizing (English) vocabulary. If, for instance, a newspaper headline reads “The president is holding a ball”, is he then having an elastic sphere in his hands, or is he heading a social event?
   Knowledge about context is called *conceptual knowledge* in Bloom’s revised taxonomy. It must be learned like learning facts.

3. Train procedures for automatic reactions

   Knowledge about facts in contexts is the prerequisite for adequate reactions to changing situations. If these reactions happen without or nearly without conscious awareness, then they are memorized in the implicit memory [7], which is also called procedural or non-declarative. The corresponding process of learning is a *training-process* in this case. Following Squire [8], trained procedures are stored in the striatum, which is a part of the brain. Neuroscientists call that part of the memory *procedural*, while they call these procedures *skills* and *habits.*
   Note that this usage of wording is closer to the colloquial use of this term, and much more specialized than the usage of the term “skills” by some schools of educational scientists.

4. Find rules behind procedures

   A very important step in learning is to find out rules that govern procedures and to store them in memory. Their conscious application is basis for thoughtful action. Following Squire [8], these procedures are stored in parts of the brain that are different from the striatum. They are parts of the declarative memory. Since in contrast to training procedures, this type of learning needs a purposeful action, and since it is stored in other parts of the brain, finding rules cannot possibly belong to the same category of learning as compared to training of procedures.
   Following [5], this type of knowledge is called *canonical* [1], since it comprises awareness of rules.
   Acquisition of canonical knowledge needs analytic capabilities.

5. Find strategies for acting

   The most advanced type of learning evolves from thinking about what would happen, if rules that are valid in one particular context would be applied to another context, or what would happen, if rules would be broken. Possible actions might then be stored as potential strategies for handling future events.
   Following [5], this type of knowledge is called *strategical*. It is the basis for creative thinking.

A cycle of learning starts typically with the acquisition of factual and conceptual knowledge in Bloom’s sense. The memorized information is stored in the declarative memory.

Provided that the information could be retrieved by the learner at will, this step of learning is seen to be successful: That piece of information has been learned by heart.

Steps 1 and 2 of learning are usually followed by a training period, which leaves procedural knowledge in Bloom’s sense in the procedural memory. The ability to retrieve this information *and* to apply it is called *skillful acting* in Squire’s wordings.

Often, the cycle is then closed by starting another cycle, without using steps 4 or 5, i.e. the cycle finishes with the acquisition of skills (in the colloquial sense or in terms of neuroscientists).

A deeper understanding can only be acquired, if the three previous steps of learning are followed by step number four, in which rules behind procedures are discovered.

Bloom and colleagues did not yet have access to newer neurological results when they created their model. Therefore, they did not distinguish between information about automatic reactions and information on thoughtful action. Therefore, they called both of them *procedural knowledge*.

Based on the newer findings, however, which were summarized by Squire, it is known that these types of information differ not only by the methodology, with which they are acquired, but also by the location where they are stored. Therefore, a clear distinction must be made between learning results from steps 3 and 4.

In most cases, learning cycles are finished after step 4. Indeed, all days’ situations might be successfully handled by application of procedural and canonical knowledge.

Step 5 is performed on highest levels of learning only. It concerns memorizing of potential actions and reactions for future events. It is not necessarily result of a verbalized way of

[1] canon = rule

thinking. It rather could be the result of a figurative way of thinking, too.

After completion of a cycle, seldom after step 2, usually either after step 3, or 4, or 5, another cycle will be initiated, either on the same level of learning or at a higher level of learning.

Having these processes in mind, a critical analysis of terms and definitions used in qualifications is now possible.

III. The EQF-Definitions for Knowledge, Skills, and Competences

Following a convention signed by the council of Europe and the UNESCO [9], qualifications are papers giving evidence for achieved degrees, diplomas or other certificates issued by a competent authority attesting the successful completion of a higher education program. Qualifications frameworks serve to compare qualifications awarded by different institutions, often from different countries.

The European qualifications framework (EQF) [10] differs from prior attempts to compare qualifications, amongst others, by categorizing learning objectives using the *three qualifiers* “knowledge”, “skills”, and “competences”. It is a particular feature of the EQF that it gives definitions of meaning of these qualifiers.

This is not a matter of course, since methods used in educational science are dominated by hermeneutical approaches, which live from interpretations. Rigorous definitions would leave not much space for these.

Bloom’s taxonomy is a nice example of advantages and disadvantages of that approach: Categories and in particular descriptions in Bloom’s original taxonomy concerning the cognitive domain [11] deviate from Bloom’s revised taxonomy [6]. Essentially, this change was not caused by falsification of a model, but by re-interpretation.

As a consequence, assessment of learning outcomes that one and the same person has demonstrated at a given point in time, could change (slightly) by changing the set of interpretation rules in the two versions of Bloom’s taxonomy.

This change was made possible by categorizing all different results of learning processes as “knowledge” in a wider sense, and by distinguishing different types of knowledge by attributes that could be replaced easily by others.

The advantage of this proceeding is that initially many people could agree to that approach, while fine-tuning is possible until a wide consensus is achieved.

The disadvantage is missing clarity and reliability.

By the way, interpretations of the other two domains of Bloom’s taxonomy, the affective domain [12] and the psychomotor domain [13], were much less successful, since until now, interpretations are too much diverging, which again demonstrates a weakness of the hermeneutic approach.

Nevertheless, Bloom’s taxonomy has its undisputed and highly appreciated value, since it cleared the way for the application of scientific methods, in particular statistical methods, to the evaluation of learning outcomes.

This is exactly what is needed in order to compare intended learning objectives and actual learning outcomes of educational programs, provided the results of comparison leave only little space for individual interpretation.

This is why clear definitions are needed.

Indeed, there are many different paraphrases on the meaning of the qualifiers “knowledge”, “skills”, and “competences”. Surprisingly, however, most of them are not very rigorous. They are often quite imprecise, or they are even contradictory.

The late F.E. Weinert, a well-reputed psychologist, who did not have the opportunity to get to know newer theories of learning, even stated in 2001: “There is no basis for a theoretically grounded definition or classification from the seemingly endless inventory of the ways the term competence is used” [14].

There appears to be a tendency, thus, to avoid the definition of terms. This applies also to prominent predecessors of the European Qualifications Framework. These are the Tuning projects [15], and the Dublin Descriptors [16], [17], where the impression arises that the authors have a clear imagination of what they mean by terms like “skills” and “competences”, but where they obviously assume that the readers share this imagination, thus making it unnecessary to define the terms.

This is different in the European Qualifications Framework [18], where the attempt is made to create definitions of terms that could be commonly accepted by educational scientists as well as of psychologists, of natural scientists as well as of representatives of humanities and of social sciences. They do not coincide, however, with Bloom’s terms.

The EQF-definitions are given as follows:

1. *knowledge* means the outcome of the assimilation of information through learning. Knowledge is the body of facts, principles, theories and practices that is related to a field of work or study. In the context of this framework, knowledge is described as theoretical and/or factual.
2. *skills* means the ability to apply knowledge and use know-how to complete tasks and solve problems. In the context of this framework, skills are described as cognitive (involving the use of logical, intuitive and creative thinking) or practical (involving manual dexterity and the use of methods, materials, tools and instruments).
3. *competence* means the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development. In the context of the EQF, competence is described in terms of responsibility and autonomy.

This is the welcome attempt to reconcile scientists of different disciplines. However, there is still a need to improve the given definitions, since in particular skills and competences could not be distinguished clearly by these definitions.

The EQF-definition of knowledge, for instance, includes terms like "theories" and "practices". With reference to the above cited model of learning, it comprises attributes of all different steps of learning, thus making impossible to clearly distinguish between different categories of the process of learning.

Does knowledge about theories in the EQF-sense include know-how of their application? If so, why is it then necessary to introduce the qualifiers "skills" and "competences"?

It might be supposed that the creators of the EQF-definitions intended to separate pure retrieval of information from application of stored procedures. Unfortunately, this has not been clearly expressed in the definition.

A similar critique applies for the EQF-definition of skills that includes the "use of logical, intuitive and creative thinking", while "competence" is defined as the "proven ability to use knowledge, …, social and/or methodological abilities, in work or study …".

What is the essential difference between these categories? Is it the difference between "use" and the "ability" to use something? Or is it the requirement that in the definition of the term "competence" the attribute "proven" is used?

Having these questions in mind, it appears as if the EQF-definitions suffer from soft compromises that prevent rigorous classification.

IV. The 4ING-Definitions for Knowledge, Skills, and Competences

4ING [19], the umbrella organization of the four councils of schools of engineering and of computer science and technology at German research universities, therefore, suggests to use a definition that is based on the learning model from section I, and where qualifiers are defined as follows:

1. *Knowledge* related to a field of work or study, means the learnt, retrievable information on facts, the context, to which facts are associated, and the rules interrelating facts to contexts.
2. *Skills* means an ability that has been acquired by training and that makes use of the implicit memory [2], to apply knowledge to *standard* situations, and to use know-how to complete *standard* tasks, and to solve *standard* problems.
3. *Competence* means the proven ability to autonomously recognize interrelations between facts and the contexts to which they are linked, to apply this ability to systematically develop new methods, and, if indicated, to apply them to changed situations. This includes application to work or study situations, and in professional and personal development.

A strong interrelation to Bloom's revised taxonomy of learning and to the cited learning model is seen, since

- knowledge in the 4ING-sense could be measured as retrievable information of factual and conceptual knowledge as defined by Bloom,
- skills in the 4ING-sense would be found as implicit, procedural knowledge (the latter being defined as in Bloom's taxonomy), and
- competences would be classified as application and further development of declarative, procedural knowledge, i.e. as canonical or strategical knowledge as defined in [5].

In a strongly condensed form, it might be said that in the sense of the 4ING-definitions,

- knowledge is learnt by heart,
- skills are acquired by training,
- competence is developed by using sense and intellect.

V. Measuring Knowledge, Skills, and Competences

Having in mind that the European Qualifications Framework defines "qualification" as a formal outcome of an assessment and validation process [18] [… stating] that an individual has achieved learning outcomes to given standards, it is necessary to *measure* knowledge, skills and competences.

This is not too difficult in case of testing knowledge, since knowledge can be retrieved, by definition. It is also obvious that knowledge in the sense of the 4ING-definition might be tested on different levels, since it relates to learning cycles.

A simple means for testing knowledge would be for instance a multiple choice test or cloze text. As an example for an inquiry on different levels, consider the question for the correct formula of Ohm's law. When testing a pupil in the last class of secondary school, a relation between voltage and current could be asked for, while on a bachelor-level, a relation between current-density and electrical field might be the required result [3].

Questions like these would be typical questions for facts in a context and the rules governing these facts. A correct response would not yet tell anything about the ability of the respondent to apply this law to a standard problem.

Indeed, one of the present authors once asked a sophomore student in an oral examination for Ohm's law, which the

[2] Earlier definitions given by 4ING did not yet include the attributive clause "and that makes use of the implicit memory". Also, the clause "that has been acquired by training" was not yet included in earlier versions of the 4ING-definitions. The latter wording has already been used by WordNet [20], an electronic lexical database that is being maintained at the Cognitive Science Laboratory of Princeton University.

[3] It should go without saying that a careful formulation of questions is needed in order that candidates are able to recognize what is expected.

student answered with a correct formula. The following question, what the symbols in the formula would mean, however, could not be answered satisfyingly: The student had some knowledge in the sense of retrievable information, but he certainly had not yet achieved competence, and, as it turned out later, he even did not have the necessary skills.

Within the framework of 4ING-definitions, skills differ from knowledge by that the learner needs not only to retrieve some information, but that s/he must also be able to apply an appropriate, *trained* procedure to solve a standard problem.

In contrast to competences, skills are based on implicit, procedural memory, while competences make use of the explicit memory. I.e.: applying skills does not necessarily require reflecting what one is doing.

The above explanation might be easily accepted for the psychomotor domain: Peeling an egg or driving a bicycle is a skill, not a competence.

Ít is more difficult to transfer this definition to more abstract domains. However, an example shows that this act of transfer is not only possible, it is even sensible, rather.

Every bachelor of engineering knows for instance how to solve a linear, ordinary differential equation with constant coefficients by the method of Laplace-transform. Once the problem is identified, it might be solved by completely schematically applied procedures. Even the steps of transform and inverse transform will be performed without reflecting the mathematics of complex integration, and just by reading out tables. This method of solving a certain type of differential equations is thus a skill in the sense of the 4ING-definition.

Testing for skills using the 4ING-definition might be done by asking for the solution of standard problems that could be solved by standard procedures, which are applied automatically and without intensive reflection of the problem, and that have been trained during studies. Actually, most written exams in engineering subjects do test candidates for skills.

Using the 4ING-definition, even assessing competences is a solvable task. With reference to the definition, it requires posing non-standard problems in the field of study or work.

Problems could be posed and solved in the context of a larger home-work, or by working out a presentation in a seminar, or by giving a more complex problem to a group that has to solve it as a team, or by demanding to work-out a complex thesis etc.

In any case, supervisors have to pose the problems very carefully, such that students must give evidence for their ability to recognize relations between facts, and to apply this information for problem solution. Supervisors must urge candidates to give account of all their decisions such that the latter could be evaluated.

Assessing competences is thus a highly demanding task for supervisors. It might well be that this is one of the reasons why some people declare that it would be impossible to test for competences. However, this is disproved day-to-day by those working successfully in human resources management.

VI. Competence Profiles

A field of work or study, in which knowledge, skills, and competences are to be assessed, might be more or less narrow, or the requirements for achieving a particular level might be higher or lower. It is obvious that a good result of assessment could be easier achieved for a narrower field or for lower requirements. A too vague specification of the field of work or study, however, is certainly not a good idea, if transparency and clarity are the main aims of using a qualifications framework.

While the European Qualifications Framework (EQF) and some other frameworks clearly define levels, most of them including the EQF do not even specify width of knowledge, broadness of skills, or depth of competences, nor do they clearly tell whether their requirements for achieving a certain level must be achieved in full, or in the average, by every candidate, or by the majority of a cohort. This is certainly a serious weak point that must be overcome urgently.

A first step into direction of a possible solution to these problems would be a detailed description of the concrete, intended learning outcomes of a field of work or study.

During the last three years, so-called sectoral qualifications frameworks have been created that apply the categorizations of the European Qualifications Framework to a coherent group of professional subjects. An example is the sectoral qualifications framework for engineers and computer scientists for the bachelor-, master-, and doctorate-level that has been worked out by 4ING [21].

In parallel, an attempt has been made to create a national qualifications framework in Germany [22]. Unfortunately, this framework is not compatible with the European Qualifications Framework. Anyway, it brings in a further categorization of competences that has already been incorporated into the 4ING-definition of the term “competence”: It is the differentiation between subject-specific competences on one hand, and self-competences, and social-competences on the other hand. (See fig. 2). The latter are sometimes called “soft skills”, or “generic skills”, though part of them are not necessarily skills in the sense of neuroscientists or in the sense of the 4ING-definitions.

Virtually all significant qualifications frameworks consider educational careers only that follow a straight way. This means that qualifications levels have been achieved in an increasing order from lower to higher, and ending up in one particular specialized professional field. More than one specialization is not normally taken into account.

However, there are enough persons having qualifications in more than one field of profession.

As an example, consider an artist with a qualification on level 7 in musical sciences, and who had a vocational training in building musical instruments first, and that finished with qualifications-level 5. It might well be that competences had been achieved during the first educational period that either are not required in the second educational period, or that were assessed to have a higher level than the average level of the first qualification, and that could be transferred to the second

(level indicator)				
knowledge	***skills***	***competences***		
		subject-specific	***personal***	
			social	***individual***
learnt, retrievable information on facts, the context, to which facts are associated, and the rules inter-relating facts to contexts; related to a field of work or study.	an ability that has been acquired by training, and that makes use of the implicit memory, to apply knowledge to standard situations, and to use know-how to complete standard tasks, and to solve standard problems.	the proven ability to autonomously recognize interrelations between facts and the contexts to which they are linked, to apply this ability to systematically develop new methods, and, if indicated, to apply them to changed situations in a		
		subject-specific	social	personal
		environment		

Figure 2. Schematic of descriptors for knowledge, skills, and competences, including generic competences

one. Such a situation could not be described adequately by most important qualifications frameworks.

Thus, for an adequate assessment, it does not suffice to specify the highest level of qualifications. Rather, any assessment must be accompanied by specifications of what has been assessed, in what professional field, in what width (i.e. which subfields are covered), and on what level. The result would be a *profile* of knowledge, skills, and competences. Such profiles are shown in Figs. 3 and 4.

Fig. 3 shows a profile of someone who has achieved level 6 in some area of expertise (“field 1” in this example), and who has considerably lower knowledge, skills, and competences in two other fields (“field 2” and “field 3”). Also social and individual skills and competences are attested on different levels.

In contrast, Fig. 4 shows the profile of an individual with the same level of knowledge, skills and competences in field 1, but with enhanced levels of knowledge, skills and competences in field 2 and field 3 of expertise, as well as in the fields of social and individual competences.

These two examples reveal two problems that have not yet been solved by the European Qualifications Framework and other national qualifications frameworks.

If fields 1, 2, and 3 are rather narrow, but complementary fields that together form a broader field of expertise, should then a candidate with a profile following Fig. 3 be given the qualification level 6? And should a candidate with a profile following Fig. 4 be given the same qualification as to the first candidate?

A competence profile is thus much more meaningful than a simple qualifications level!

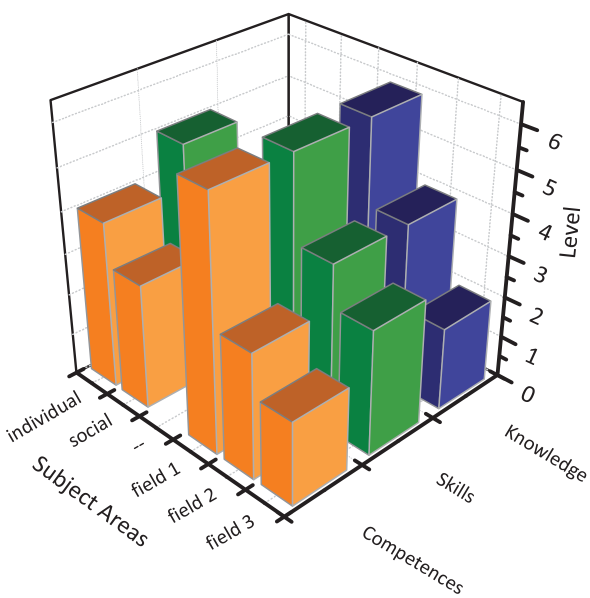

Figure 3. Competence profile with limited width on level 6

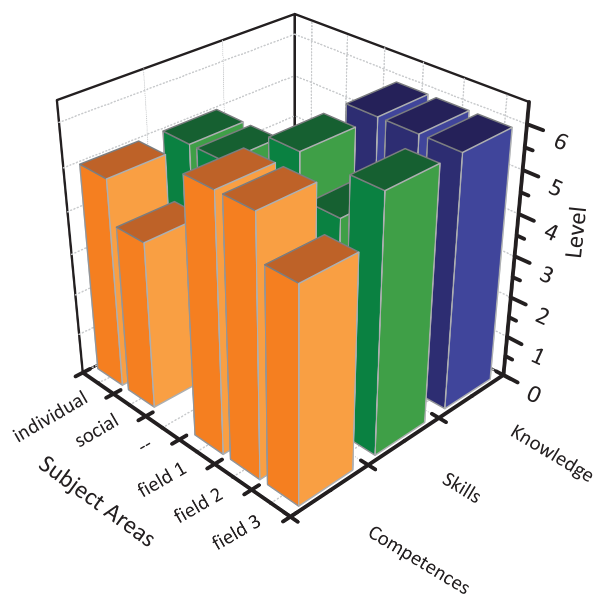

Figure 4. Competence profile with a wider width

4ING suggests, therefore, completing qualifications frameworks, in particular the European Qualifications Framework and related national frameworks, in a way that such profiles would be specified following commonly accepted rules. A characterization by just one number, namely the level, is certainly not enough.

VII. Conclusion and Outlook

Qualifications frameworks are tools for transparency and comparability of qualifications. The EQF uses the categories “knowledge”, “skills”, and “competences” to describe qualifications on several levels. It has been demonstrated that a more rigorous definition of these categories could be given based on accepted learning models.

With these definitions, “measuring specifications” are made possible that enable educators to assess whether a certain level of qualification has been achieved.

A suggestion has been made to better characterize competences, and to specify qualifications profiles in order that they could be used as tools for comparison. However, to make that tool efficient and effective, much remains to do.

A further development of qualifications frameworks with respect to improved competence profiles appears to be sensible.

Such an improved framework might include refinement of the class of subject-specific competences, e.g. by subdivision into Bloom’s taxa of being able to analyze, to evaluate, and to create.

Another focus might be a thorough analysis of individual and social skills and competences. These are certainly not exclusively competences in the sense of the 4ING-definitions. In fact, they are a combination of specialized knowledge, skills, and competences in some subfields of psychology and sociology.

For a classification into one particular level of qualifications, it must be clarified how this level is determined from particular levels of the profile.

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Implementation of An Engineering Educator Graduation Program for the formation of New Skilled Engineering Teachers

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Abstract — **COPEC - Council of Researches in Education and Sciences education team has designed a new program in graduation level: the Professional Engineering Education. The goal is to improve the formation of the engineering educator providing them with all the competencies needed to teach at the state of the art with the best available teaching technologies. The PEE Program offers two graduate degrees: the Master of Science and the Doctor of Philosophy. It is a very dynamic and rich program, developed in modules, following the trend of global formation of professionals, mainly to attend the need of a prepared engineering educator to act in the several different cultural environments, which mobility has imposed as a fact of life for researchers and teachers at graduation level. Not to mention the necessary new competencies of educators such as: evaluation management; development competencies; communication skills; teamwork; ethics and intercultural competencies. So this program has been designed to fulfill this lack of engineering educators.**

Keywords: Education sciences, competencies, technology, intercultural skills, qualification

I. Introduction

The education in any level is watching the deep transformation of world in every level trying to change in order to accomplish its noble mission of prepare future generations of people to work hard for the betterment of human conditions.

Engineers are one of the main agents of promotion of development in the world and the formation of a new kind of engineer is the priority to face the new world environment, which aspects are not always positive for a large proportion of humanity [01].

Engineers as problem solvers should be more aware of the impacts of any development also in social level once the impacts of unification of world in any level has consequences for the entire world. International experience shows to be one of the best ways to teach at the present conditions once mobility is higher, communications are easy and accessible for the majority of the world population.

Some educators advocate that the world as the classroom for engineers has a possibility since men started to navigate to far seas. The world has been and now more than ever where engineers can find inspiration, knowledge, employability and opportunities.

Education without any doubt is a science in constant construction like any area of men's life: dynamic, challenging and alive.

One key question of how to form the best professional is always being made and answers have been so many that it is difficult to say it is this or that. Many Institutions of Education have been seeking goes the best ways to provide high level education goes their society worldwide. Anyhow the quality of the Institutions of Education implies several aspects such as the: quality of classrooms, labs, libraries, communication systems etc; students ' services, qualification of human resources; pedagogical scientific quality, credibility as a good institution. However quality in education speaking about what is called of technical competence is essentially the use and dominium of the cognitive means of teaching learning process as well as the available technological means. This level of quality of education has the dependence and straight relation to the teacher and his/her qualification and competence. Good programs have good motivated teachers in addition to modern installations and dynamic planning. The Faculty of any Institution of Education is one of the most important element, which provides or not its qualification of excellence [02].

In order to fulfill a lack of engineering educators for high education for engineering and technological fields in the country COPEC - Council of Researches in Education and Sciences education team has designed a new program in graduation level: the Professional Engineering Education. The goal is to improve the formation of the engineering educator providing them with all the competencies needed to teach at the state of the art with the best available teaching technologies.

The so called PEE Program offers two graduate degrees: the Master of Science and the Doctor of Philosophy and it is a very dynamic and rich program, developed in modules, followed in several countries in the world. It follows the trend of global formation of professionals, mainly to attend the need of a prepared engineering educator to act in the several different cultural environments, which mobility has imposed as a fact of life for researchers and teachers at graduation level [03].

II. Historical Aspects of Globalization and Education

Along the History it can be seen the human achievements in altering and dominating nature in favor of better ways of surviving. This is how technology was born and prevails improving and now more than ever in much sophisticated levels. Men can now more than ever reach levels of comfort, healing of diseases, increasing age level expectations, moving around the world, watching the news and communicate in real time.

All this thanks to the development of sciences and technology and engineers all over the world are in many ways shaping a new life style, helping to save lives, making transportation faster and more secure, enhancing communications and etc. This isolated aspect – the development of sciences and technology, helped to make the globalization phenomenon a reality once more in human history. In the past Alexander the Great was may be the first leader to promote the globalization through wars and invasions followed by Genghis Khan, Cesar and others. Now the big corporations are promoting the globalization in a more subtle way, may be less painful and traumatic but still invasive. If it is good or bad the future will tell us, there are pros and cons being widely discussed but the fact is that it is there. It is the evolution of the capitalism system predominant in the world and sciences are occupying its place of relevance in world scenario [04].

One positive aspect of present world is that the nation's world wide is recognizing the importance of engineers once they are the ones that make possible the world goes round.

In academic midst the discussions about the formation of engineers are receiving more and more incentive and many real actions have been applied with success. Many new engineering programs have been conceived and are working well, more flexible programs, more investments in labs and equipments, more exchanges programs and so on. It is the education evolution in order to adequate the formation of engineers for the future. So Future is the keyword once the world is changing so fast as well as the labor market.

The Universities and their Schools and Institutes have been sacrificed by the so called globalization that imposes certain needs that are absolutely new and many of them not so necessary. It is no longer a matter of using multimedia equipment in classroom but fundamentally to look for new more appropriate and captivating contents to present to the new plugged students. Besides all of the technical and pedagogic aspects it is necessary to think about the psychological aspects of this great and passionate process of teaching. For the good or for the evil, there it is this new socioeconomic and political world of contrasts in which only the education can really change for better [05].

Speaking about education for best, the professionals who leave the universities today leave already with a stock of knowledge that is partly obsolete and s/he has to run fast to adapt to the new job market. Is this the fault of the University? The answer is no, the University has been serving the society for centuries and without interests others than the investigation and the improvement of the knowledge that generates benefits for the humanity as a whole.

What about the teacher? The new teacher has to preserve the curiosity, to urge the capacity of the students' inquiry; he has to teach them to learn and not to suffocate them with a mountain of scientific and technological knowledge, that today the teacher does in the anguish of teaching better.

III. Some Considerations about Globalization

Globalization could be defined as the transformation of the world in a global village, that means "closer contact between different parts of the world, with increasing possibilities of personal exchange, mutual understanding and friendship between "world citizens", and creation of a global civilization." Nevertheless analyzing Globalization on the economical-financial side it began in the 80's with the integration at world level of the economical and financial relationships. It presents two aspects: the negative and the positive.

As positive aspect is the cultural and commercial exchange among people and nations; in the course of two generations the gap between the industrial and the developing regions narrowed substantially everywhere; the overall poverty, when defined by health of population and life expectancy, as well as by income has diminished [06]. By the other hand the results of globalization have not been what was predicted when the attempt to increase free trade began, and many institutions involved in the system of globalization have not taken the interests of poorer nations, the working class, and the environment into account; developed countries are the largest beneficiaries of this system and they are becoming richer while the developing countries are becoming poorer.

The discussions about Globalization in general show a bad scenario and the future is unpredictable once it is not possible to foresee the big players' next movement in such huge business game of fighting for markets.

IV. Science and Technology in global world

Scientists for centuries can see the world as a unified heterogenic content and capable to comprehend the whole. In a sense, science is responsible for the idea of globalization. Furthermore, as a system of knowledge, science has been uniquely successful at building widely shared understandings that transcend political and cultural differences.

Information Technology known as IT is a driving factor in the process of globalization. Improvements in the early 1990s in computer hardware, software, and telecommunications have caused widespread improvements in access to information and economic potential. These advances have facilitated efficiency gains in all sectors of the economy. IT provides the communication network that facilitates the expansion of products, ideas, and resources among nations and among people regardless of geographic location. Creating efficient and effective channels to exchange information, IT has been the catalyst for global integration [07].

V. THE NEW WORK MARKET

Science and technology innovations have shaped the present work market in such a way that from now on "changing" is the role and not the exception. It is a changing world and a changing work market in every level. Technology has enhanced work place that means less hand work and more mental work. Thanks to information technology the workplace is now team-based. Management styles have changed with horizontal structures where everybody is responsible for the results of the work requiring less supervision. For workers in any level the expected profile comprehend attitudes and behaviors to work in teams. The job environment is different due to the way that companies run the busyness now; jobs positions are displaced, others take places and shifts are always changing in according to the new necessities.

Among the dramatic changes in work market it is noticed that now more jobs are part time; more people are self employed; less staff needed to accomplish works; paid and unpaid overtime work are increasing; global competitiveness; flatter organizational structures; companies downsizing, less job security [08].

Human beings are living now in a changing work environment full of surprises and unpredictable events in a daily basis. The best way to overcome and to survive is to be prepared achieving knowledge and be willing to develop new skills.

VI. HOW BEST TO EDUCATE THE NEXT GENERATION OF ENGINEERS

The global expansion is here to stay.

Advanced communications technologies continue to alter the way businesses and societies conduct themselves and interact with each other. Today's engineers are expected to work globally-collaborating with team members located in various countries with diverse languages and business cultures to engineer products and services that insure the company's competitiveness in the global economy.

How best to educate the next generation of scientists and engineers, who will enter a workplace that has become truly global environment?

There is not only one answer and the point is that the engineering schools are the ones responsible for the formation of generations of engineers who are among others the main responsible for the development of sciences and technology seeking for the betterment of humanity.

Despite the negative aspects of globalization all the scientific and technological advancements have one main goal: make men's life better. That is why machines were designed to do the hard work so that men can have more time for other more pleasant work; the search for new drugs to defeat diseases, to live better and more and so on. Nevertheless all the achievements bring also new situations that are not always positive that is why engineers should to be more aware of social responsibility, to be aware not only about the economic and environmental issues but also the impact of new technologies in the society. Any isolated event in the current world in one or another way has some effect in other regions of the planet and sooner or later they will be felt. To deny it is the same as to "sweep the dust under the carpet" [09].

So, summarizing the formation of the engineer for the future must consider besides the strong basis in basic sciences and basic sciences of engineering the development of:

- Communication skills;
- The willing to learn all life;
- Positive attitudes and behaviors;
- To work in teams;
- Responsibility for actions and results;
- Respect to diversity;
- Entrepreneurship;
- Self employability;
- Self management.

May be the main skill is the development of the capacity to see the opportunity of a new work, a niche that can be explored and generate good results no matter where it is. The experience of studying abroad is an efficient way to give the students an opportunity to get in touch with other cultures and to develop communication skills in an upper level. The learning of languages and the sensitiveness to behave properly are some the positive results of this kind of experience. It has to be a structured program with defined goals and flexible schedule [10].

VII. THE CHARACTERISTICS OF THE NEW PROFESSIONAL

In this new world scenario the skills, knowledge and training that are required are fundamental to survive in the changing labor market. It is imperative to be able to manage technological changes, be creative, take calculated risks, manage stress, think conceptually and recognize and respect people's diversity and individual differences.

The knowledge required includes the general knowledge of the busyness, the understanding of the total organization, at least a general knowledge about computers among others. The academic knowledge must provide the basic foundation to get, keep, and progress on a job to achieve the best results.

It is necessary more than ever to develop multi skills, communication skills in order to work in teams, to be willing to retrain, to study constantly in order to learn new technologies rapidly; it is life-long education [11].

VIII. THE PROFILE OF 21ST. ENGINEERING EDUCATOR

Specifically speaking about the profile of next generation of engineers committed with education, working in classrooms it is important to discuss some points such as the basic research that is now recognized as an important element in the development of high technology. Universities are in a good position as they have been recognized by the governments and industries as crucial to foster their development.

The formation of good engineers and professionals in technological fields is fundamental for the governments, the industries and societies. The relevance of teaching practice is increasing in order to provide good teaching and guidance for the future professional, researcher or teacher.

The profile of an Engineering Educator is based on three fundamental premises [12]:

- A solid base of disciplines of Sciences of Engineering is the basic demand for the professionals of Engineering and Technology fields dedicated to the Education.
- A good knowledge about Education in Engineering is in the same way important and a course of appropriate training should be equivalent to one semester in university (a minimum of 200 hours) in content terms.
- A minimum of a year of practical work as professionals in one of Engineering and Technology area dedicated to the Education.

IX. The PEE Program

The PEE program follows the patterns of IGIP - International Society for Engineering Education registration for Engineering and Technology, the qualifications and professional experience at an advanced level. This society provides a title that has been recognized in several countries in Europe and now spreading all over the world.

The formula for the title "ING-PAED IGIP" is:

Qualification in Engineering
+
Training of Education in Engineering and Technology
+
Practice in Engineering and Technology Education Area.

The engineering qualification should correspond preferably to "Europe Ingenieur (EUR-ING)" qualification for FEANI. In Brazil it follows the defined patterns for CFE/CREAs – Federal System of Engineering in the engineers' case and of the organizations responsible for the other professionals of Technology area.

X. Admission Requirements

The basic candidate requirement for admission is [13]:

- a bachelor's degree in science, engineering, or technology, or in such fields as computer science/engineering, electrical/ control engineering, industrial engineering, environmental engineering, manufacturing engineering, materials science and engineering, mechanical engineering, or management, etc.
- Students with other backgrounds will be considered based on their interest, formal education and experience in teaching.

XI. Course Information

The Master Degree in Engineering Education requires 30 credits in ECT's of graduate studies. The 30 credits consist of a minimum of 12 credit hours of coursework, plus 12 credit hours of any combination of coursework, independent study, directed research or thesis that complies with the following constraints: if there is a thesis, it must at least 6 and no more than 12 credits; there can be no more than 9 credits of directed research; and the total number of credits from the Management Department cannot exceed 14 [14].

The minimum of 12 credit hours of coursework must include a minimum of two credits each in at least four of the seven core areas. The coursework should be selected in consultation with an advisor from the EE faculty. All full-time students are required to participate in the non-credit seminar course.

XII. The modular curriculum

The PEE curriculum is a modular one and it is as follows:

Module Description	*Credits at least*
Core Modules	**8**
Theoretical and Practical Engineering Pedagogy	6
Laboratory Methodology	2
Theory Modules	**4**
Psychology and Sociology	3
Ethics (1 credit) or Intercultural competencies (1 credit)	1
Practice Modules	**6**
Oral Communication Skills, Scientific Writing	3
Working with Projects	1
Media, E-Learning, Computer Aided Technologies	2
Elective Credit Points	**2**
Electives	2
In Total	**20**

Each module has the goal to enhance the development of a competency so necessary for the improvement of teaching styles. There is a demandfro educators connected with the new students'Profile.

XIII. Conclusion

It is a reasonably flexible program that is developed in according to the needs for the accomplishment of the main goal to form engineering educators.

The main characteristic of the program has been to lead the attendees to think "out of the box" imprinting the notion of dynamic teaching environment that is necessary in order to form the new professional. It has been designed in order to fit the necessities of professionals and institutions interested in the improvement of career and quality performance.

All the course evaluations have been very positive. The attendees are satisfied with the approach and the content of the courses. It is a great achievement for academic midst once it can provide for engineers and professionals of technological areas the opportunity to update the knowledge about education as a whole.

It is important to point out that it is a very dynamic program once the content of the courses can be developed constantly taking into account the characteristic of the groups. This aspect is relevant because it helps to overcome the obstacles such as communication problems, stress management and so on.

The number of professionals interested in the program is growing and it is expected a larger number of attendees for next group.

Besides the professional receives a diploma that is recognized national and internationally.

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enginy@eps: Motivating the Engineering Courses

Social Valuation as a Motivating Factor

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Abstract—**This paper presents an academic initiative to increase the motivation of students for engineering topics, and discusses the results obtained. The initiative is a journal where students may publish, both in paper and in electronic format, the final reports of their laboratory works or research activities. The name of the journal is enginy@eps. The existence of this journal becomes an external element for motivating the students, since their documents are going to be reviewed by an editorial staff and are going to be published out of the classroom. The collected data shows that social recognition is still a useful element to motivate the students in technical courses.**

Keywords- student motivation; educational innovation; formal writing profile

INTRODUCTION

In the last subjects of engineer courses, students participate in autonomous works, research activities and laboratory sessions where it is necessary to go further than just to apply previously learned concepts. This kind of activities requires a lot of time and hard work not only from the students but, also from the teacher. Finally, once the work is evaluated for the course, it is usually forgotten and often the work conclusions are not used anymore. So, it seems contrary to the student's and to the teacher's motivation to foresee that their efforts will not be useful to anyone else, and that their work will be forgotten when the course ends. That situation is not a good motivating factor for the student and, of course, for the teacher.

The student motivation is a complex topic, and it is difficult to quantify [1]. In some cases, the same thing does not motivate all students at the same time. Two factors that impact on student motivation are: the social valuation and the perception of the expectation of success [1]. It is important to note that both factors are part of a multiplication equation, so if anyone of these factors is zero, the result is zero too. This means that, the student must find some positive attraction toward the educational activity, but in addition, it is necessary a positive perception regarding the accomplishment of the learning activity. There are a lot of learning environments proposed to increase the students' motivation, as an example in [2] and [5-6] a game based learning environment is used to increase the motivation of students in different courses.

Furthermore, the students in first courses, in general, have initiated the Engineering careers without a clear idea about the topics and issues related with those courses. They may have no idea about the concepts and methodologies involved in their engineer courses. And they have difficulties to explain the reasons why they have selected these particular courses instead of some others. This initial confuse situation may be a disinclining factor; and it is difficult to know how many students leave the recently initiated studies by that reason. In [7] the authors propose to design initial courses with extensive active learning components in cooperative students teams as an effort to retain those confused students. The same situation may be identified when pre-university students have to select their university studies.

Some different solutions have been proposed in our University to help students to solve this confuse situation as soon as possible: pre-university labs, adaptation courses, classrooms open door day, or talks about the features of different courses. All these solutions have a point in common: the university presents the information about their courses mainly from an institutional point of view. These solutions fail to provide more information about the real activities developed in the classrooms or information directly obtained from others students.

From another point of view, but related to the proposed work, it is necessary to take into account that, all engineering activities and results have to be explained and summarized in any technical document. So, it is not only necessary to learn good competences in technical engineering topics, but it is also necessary to acquire good technical writing skills. Cockrum et al. in [3], propose some ideas of how to design writing courses, to help students to acquire those necessary generic competences.

In this study, we propose to learn writing competences not in a separate subject, but in several subjects at the same time and in combination with each specific subject contents.

Laboratory and autonomous works typically finish with the presentation of a document, which is, in fact, a technical document. In that case, the student, with some minimum requirements proposed by the teacher, writes the document using a free format. The second goal of this work is the coordination of several subjects to propose the same template format for all kind of educational activities. So, not additional documentation must be elaborated by students, it is only necessary to adopt a common document template and some common writing requirements, like researchers when they want to publish a paper.

Seven different subjects have been selected to participate in this work. They have all revealed positive enhancement in both goals: the motivation of first years' students, pre-university students and authors students; and increasing the writing skills of engineering courses.

INITIAL SITUATION

Any technical course is organized in several independent subjects distributed in time. The student is motivated to learn isolated concepts in each subject and it is usually expected that the student will be able to mix those concepts and construct his/her own knowledge. Another important characteristic is related to how the concepts are learned. In traditional education methodology, it is usual to transmit the concepts from teacher to student using oral sessions. The model is changing and the main idea is that the teacher does not control the knowledge, because it is freely accessed through new technologies like internet. Nowadays, the student is in the learning centre and the teacher helps the students to construct their own point of view about the concepts.

These changes in the teaching methodology lead to more individual and in group homework, and cooperative learning activities. Those activities require a lot of time from students and from teachers in tutoring processes. In general, this kind of activities concludes by writing a technical document, which is a valuable element for the evaluation process. Those works and documents are only used for evaluation purposes and, at the end; they are stored in a box or bookcase and forgotten. In that situation, only the students and the teacher know the content of the work, since information is not shared outside of the classroom.

From the motivation's viewpoint, this behavior is not a positive factor: because both the students and the teachers keep in mind that the unique purpose of the work is to evaluate the learning process. But, what if there was a possibility of public diffusion of the work? This new feature may increase the students' motivation to do their best.

Usually, in actual fractioned knowledge courses (divided in isolated subjects), another teachers and students do not know what kinds of activities are developed in each subject, because those activities are made in the classroom with the closed doors. So, students have not a previously clear idea about the subject which is applying for. Nevertheless, that situation may be worst at the starting point of the studies. In that case, they not have sufficient resources, examples or other students' comments to discover what kind of learning activities are carried out in the university subjects.

Another aspect that has to be pointed out in this section concerns the first degree project. In technical programmes, the students must develop an independent work, in which the student should plan, carry out and report a research work. In general, the degree project concludes with a written report of the work and an oral presentation to a group of three likewise selected teachers. The same way as learning activity reports, the degree project reports are collected in the university library and forgotten there. Although, much time has been spent on those reports, they finally (and unfortunately) end up in some university bookcase. Obviously, no all project reports are suitable for public diffusion, but with a good selection, why not award the best reports with a "better life"? Maybe the expectation of a public recognition of the degree project could be a good factor of motivation to do the best.

Writing good reports may be one of the less developed skills in technical courses. Obviously, any student writes a lot of reports, but each teacher uses its own requirements adjusted to the evaluation process, so no common organization or features are shared. In fact, students just adopt the new template without any additional comprehension. No time is spent in learning how to write better reports, how to decide which information is useful and which is not, or in any other considerations about technical writing style. In research environments, reports are continuously used to explain the results of projects, and documents must follow some style if those reports have to be included in a journal. That is the same idea, but applied to student reports.

OBJECTIVES, PLANNING CHANGES AND METHODOLOGY

The proposed learning activity, for increasing the motivation and the coordination between subjects in university programs, is the publication of an annual journal called "enginy@eps". The journal opens one alternative to make classroom and project reports public.

Proposed Objectives

The publication of an annual journal was proposed with the following main goals:

- To introduce a motivation element for the students. A selection of students' works will be published in "enginy@eps". So, those students are motivated to do their best and to expose their works to readers. Furthermore, the readers (students and teachers) will be motivated to participate in the next issue and could help to create an adequate atmosphere between new and last year students.
- To introduce a motivation element for teachers. Without any public exposition of what is done in each course, it is difficult for teachers to make profit of learning activities of previous courses. So, by showing the learning activities that students develop inside the classrooms and during their degree projects, it may be possible to improve the next courses contents. On the other hand, as the students' works are not public, there is not any motivation to change the learning activities. But, when the learning activities results are published, those may be used as technical documents for future learning activities.
- To improve the technical documentation writing skills during the learning process as a multi-course learning objective. The students' papers review process may help to learn better writing and document organization skills. Although a lot of technical documents are generated by students in several courses, the student writing skills are not included as a goal of any technical course.

Courses Planning changes

The initial planning of the subjects involved in this study has been modified in order to incorporate the new learning activity. One of the most important changes is related to the activity perception by students. The proposed changes should be introduced without high increment in the student's work. So, several different options have been used to incorporate the needed changes:

- Without making major changes to the subjects to include this project. In that case, there is an activity which may be adapted easily. An example is when all students have to write a project's documentation or have to perform an experimental project, in groups of a few students. The project is related with the subject topics and each group has to deliver a report with the obtained results. In order to adapt those kinds of activities to the context of the presented study, the students have to write the project report according to the specific format defined by the enginy@eps publication.

- Adapting an existing activity but including, at the beginning of the course, some guidelines, in the form of a paper template. The different sections of the technical document (introduction, objectives, design, implementation, evaluation, conclusions) are briefly described so the students get a better idea of what they should include in each section. They are encouraged to write the Introduction and the Objectives in a simple language, as for a non-expert reader, and then to change to a more technical language for the rest of the paper.
- A new learning activity is included in the course. For instance, developing an information research work. After having introduced the students in the basic general knowledge of the subject, different topics on actual and emerging topics are proposed to them. These topics are distributed among groups of two or three students that have to elaborate on them. As a result of their research, each working group have to write a four pages article, following the journal format, which has to be presented to the rest of students of the course through a short presentation with slides in the classroom. The objective is to evaluate the autonomy of the students to seek information on existing technologies and their ability to transfer their knowledge, as well as to asses the satisfaction that it entails.
- Some previously planned activity is substituted by a new one. Before, the students had to write a homework report, but now, it has been substituted by an oral presentation together with the proposed paper format.

The changes previously described do not only impact on the activity planning, in some cases, they require new elements for the evaluation process. The new methodologies in evaluation techniques have to be adapted because the activity changes do not only modify how students report the activity conclusions, but they also modify how the subject topics are learned by students.

TABLE 1. INITIAL QUESTIONNAIRE

	Question
Q1	I like this subject
Q2	The subject topics are related to my personal expectancies
Q3	Sharing the project results is important for me.
Q4	My effort is enough to accomplish the goals of subject
Q5	I am concerned about others students having better results than me
Q6	I have confidence I will understand the concepts of this subject
Q7	I am motivated to view my work on a public journal
Q8	I am able to write a good paper
Q9	Writing is a hard word
Q10	Value from 0 (not interesting) to 10 (very interesting) the grade of motivation about viewing your name in a public journal.

TABLE 2. FINAL QUESTIONNAIRE

	Question
Q1	Writing the journal paper has increase the motivation for the subject
Q2	The motivation in the university degree has been increased with this activity.
Q3	It is important to write the results of my projects
Q4	This activity has contributed to accomplish the subject goals
Q5	I am not concerned about comparing the project results with others students
Q6	Finish the paper has been important for me
Q7	Writing is a hard word
Q8	Value from 0 (low) to 10 (high) your capacity to accomplish the activity.
Q9	Value from 0 (not interesting) to 10 (very interesting) the learning process developed during the writing activity.
Q10	Value from 0 (not interesting) to 10 (very interesting) the grade of motivation about viewing your name in a public journal.

Additionally, all subject teachers involved in the study have designed two questionnaires to quantify the impact on motivation for writing and publishing activity. The first questionnaire, see Table 1, collects the initial motivation of students when the activity is proposed. In fact, in some cases, the activity is not different from previous years, and only the technical summary format and the idea of possible election for publication are introduced. Each professor, according to the subject planning, has introduced the required changes. Table 1 shows all questions answered by the students when the activity starts. All questions can be answered within the range from 1 point (disagree) to 5 points (completely agree).

The second questionnaire has been filled by the students at the end of other activity, previously to the selection of the best papers for publication. Some questions remain unchanged intentionally and other try to measure how the student has perceived the activity.

Review Methodology and accepted papers

The review process has been organized by the corresponding teacher within each subject, but following some common review criteria. The objective of this process is to select the best and the second best papers which should be proposed to the editorial staff for the final review/accept process.

The review process for each subject has been developed in different ways, depending on the teacher's methodology. Some alternatives are:

- First, all the students had to deliver a first version of the project. After reviewing all the papers, the three best works were selected and the teacher suggested some changes to the authors. Finally, the selected students delivered the final version (camera ready version) and a second review was done to choose the paper that was proposed to the editorial staff.
- After reviewing all the documents, the teacher talked individually to each student, showed them the main errors both in the technical part and in the paper itself, and gave them some advices. Only the best papers' authors were requested to improve the document following the suggestions given to finally propose their paper to editorial staff.
- The different reports presented by all authors were available to all students and the evaluation was performed following a peer-review process where the different groups evaluate the other ones with the help of a template in order to ensure a homogeneous evaluation. The final grade of each project was calculated from the average value obtained from each group. Finally, the best evaluated project was proposed to editorial staff.

In summary, the strength of this academic activity is that it does not change significantly the methodology from the teacher perspective, but it does change a lot the perception of the students about their work and the relevance of having good writing skills. They learn that they should not focus only on the concepts or physical implementation, but they should also focus on communicating the results.

All teachers involved in the study were part of the editorial staff, so finally, all documents proposed were reviewed and accepted by all of them. In order to help the internal organization of the editorial staff, the technical courses were grouped into five different categories: building engineering, computer engineering, electronic and automatic engineering, telecommunication engineering and mathematics. One member of each area was elected as an area chairman with the following functions:

- To promote as much as possible the participation of the subjects associated to the category.
- To manage and coordinate the review process of the papers in the area.
- To maintain the area in communication with the rest of the categories in order to share best practices.

The described staff organization has been introduced as needed and allowed the participation of even subject from any technical courses present in the Universitat Illes Balears.

THE JOURNAL "ENGINY@EPS"

The annual journal called "enginy@eps" was proposed to the university community as a local initiative to promote the activities developed in technical courses at the university. The initiative opens a new space where educational works are shared between all university community members.

At present, the publication process has been performed for two courses, so the results of this study show how this kind of activity, which aims at improving the students' motivation, evolves when the students share their educational works and can read previous published works.

First year: enginy@eps is born

The first edition of the journal published 14 educational works of 9 different subjects from electrical and telecommunications engineering. All papers included were based on laboratory activities or individual research projects following some of the previously mentioned methodology changes in the subject planning.

The first edition of "enginy@eps" included 450 copies; see the cover sheet in Figure 1. The journal was distributed between students and teachers of the Engineering faculty, and some copies were sent to pre-university schools. In fact, two weeks after the presentation day, the copies were finished. That is not a scientific result, but shows how good the new publication was received by readers.

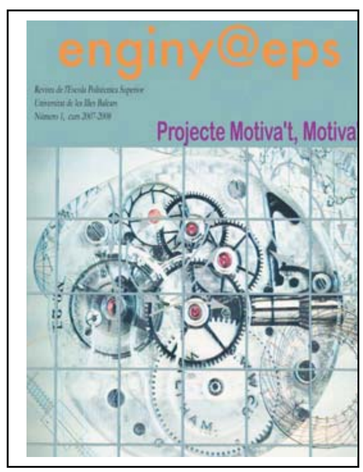


Figure 1. The "enginy@eps" cover sheet of first edition.

In that edition, some aspects employed most of the time and work of the editorial staff:

- Defining a good and easy paper-template to facilitate the writing process as well as the organization of the information for any kind of works.
- Financing the activity with external support.
- Designing the journal image, incorporating the final versions of papers and carrying it to the press.

At the end of that year and as a result of the new journal, new teachers were involved with the project. A lot of new ideas and contributions were received from the university community, promoting the inclusion of others technical courses for the next edition.

Second year: expanding the initial objectives

In the second edition, two new sections were introduced with new initial objectives:

- *Research works*: degree project reports or internal reports about new technologies were considered to be pubished in the journal. The main goals of this section are to contribute in the difussion of students projects and to motivate for reading technical information. This section starts with 6 papers from diferent degree projects, but also from teachers projects.
- *Open Section*: With the aim to contributing to create a collaboration atmosphere among students and teachers, this section publishes diferent opinions about a central topic. The central topic is selected by the editorial staff and different contributions are included: from school managers, from interview with students, from external institutions, ...

Moreover, a new impulse in the design was introduced. The journal now presents a modern aspect, with some information about internal sections on the cover sheet. See the second edition cover sheet in figure 2.

Figure 2. The "enginy@eps" cover sheet of second edition.

The second edition of "enginy@eps" included 900 copies. The journal was distributed between students and teachers of the Engineering faculty, pre-university schools and some copies where sent to other universities and external institutions.

From the point of view of management, an open journal management system [4] was adopted. The new journal management software allows the creation of an electronic edition of the journal, increasing the capabilities of difussion. By the moment, the electronic edition of the journal is used in combination with paper edition, because the journal gains more visibility and impact if it exists physically (in paper).

The impact of the journal's previous edition on students works has been noticed by teachers. When the writting activity was proposed to the students, they had a reference in their mind (last year edition). In fact, some subjects used the last year reports to improve the educational activities in their laboratory or classrooms. Last year edition has been incorporated in technical courses as an additional reference, useful for students who applied to the course, but also, usefully for other courses as an information source.

In the second year of this activity, our feeling is that the journal is a useful means to motivate the students. As soon as they had the previous issue in their hands, they expressed a lot of interest and checked it with attention. Although it may not be measured in objective terms, this is a clear indicator that social recognition is a strong motivating factor, as already stated in the literature [1].

RESULTS IN MOTIVATION

The impact of the journal in the improvement of the educational activities and on maintaining the communication between university communities may be observed in how the journal has been received and incorporated as a new tool for educational purposes. But the goal of this study is on the impact of the journal on the student's motivation.

The results in motivation are obtained from two questionnaires answered by the students at an initial stage of the writing activity and at the end of the activity, previous to the final selection of best paper for publication.

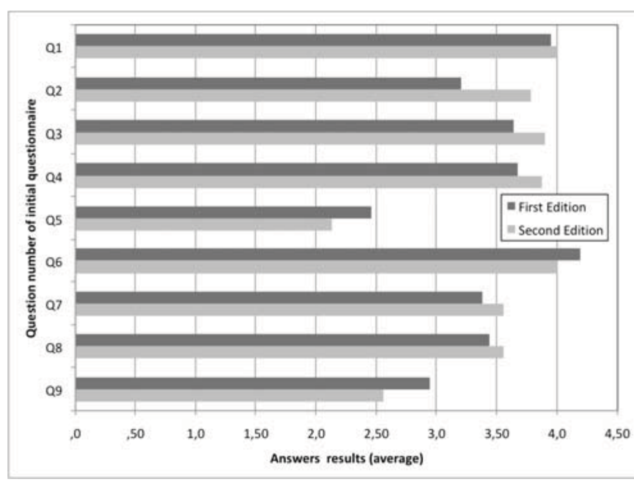


Figure 3. Initial questionnaire results evolution.

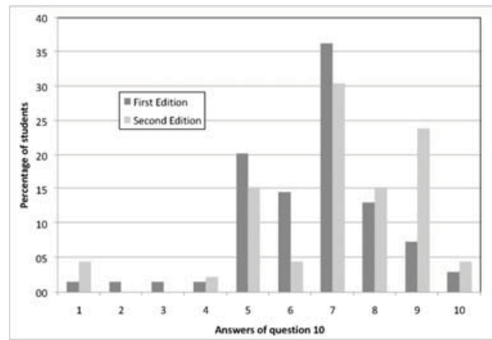
Figure 3 shows the average values initial questionnaire for both editions. It is important to remain that the students answer questions Q1 to Q9 with a maximum value of 5, while the question Q10 can be valuated until 10 and is not showed in Figure 3. Some conclusions can be obtained from the results chart:

- All students agree to consider that they like the contents of the subject and that their effort to accomplish the subject goals is enough.
- Question 3 shows how the students are increasing their interest in sharing the results of their works with other students. While the results of question 5 reveal insouciance by the comparison between students' works. These results are good for this kind of activity, because the external review of the works is a necessary step in the publishing process.
- The positive trend in the interest of students in the publication of their works is reported in the results of question 7. This may be considered an important indicator (activity valuation) of the impact on motivation. Although the values of first and second editions are similar, the number of students involved in the project was higher in the second edition than in the first one.
- Evolution of the questions 8 and 9 answers results may be considered a direct consequence of the first edition impact. While in the first edition writing a paper was considered a hard work, this process is considered less hard in the second edition, perhaps the final goal is perceived as a real fact (previous edition was published previously).
- Finally, the results of question 10, see values in table 3, may be considered a second important indicator (motivation for the activity) of the impact in motivation. The second edition impact in the results may be observed in the increment of the initial motivation.

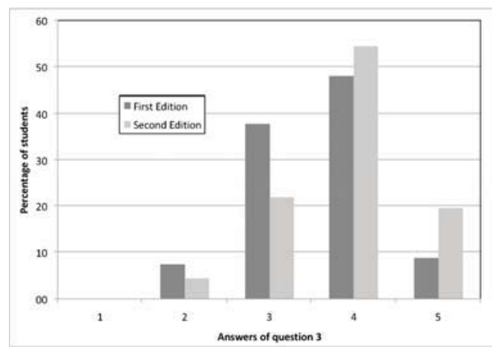
TABLE 3. INITIAL QUESTIONNAIRE STATISTICS

	Average		*Standard deviation*	
Editions	***First***	***Second***	***First***	***Second***
Q1	3.9	4.0	0.7	0.7
Q2	3.2	3.8	0.9	0.9
Q3	3.6	3.9	0.8	0.8
Q4	3.7	3.9	0.7	0.8
Q5	2.5	2.1	1.0	1.1
Q6	4.2	4.0	0.7	0.8
Q7	3.4	3.6	1.0	1.2
Q8	3.4	3.6	0.8	0.7
Q9	2.9	2.6	1.0	0.9
Q10	6.9	7.3	1.7	2.1

In Table 3, it has been collected the average and standard deviation of the initial questionnaire answers. The standard deviation is an indication of dispersion in the answers. As the values of possible answers are integers, a standard deviation lower than 1 indicates that the average is a representative value, while a standard deviation greater than 1 denotes a high dispersion in the answers. Taking into account this observation, only questions Q5, Q7, Q9 and Q10 show a standard deviation greater or equal to 1. The reason of this may be explained by the histogram of answers. In all previous enumerated questions, there are students' answers in all possible answers options. It could be due to the fact that the questions may not have a clear meaning. This comment may be observed in Figure 4, where the histogram of answers values of initial questionnaire question 10 and question 3 are shown.



(a)



(b)

Figure 4. Histogram of answers values of initial questionnaire. (a) Question 10 and (b) question 3.

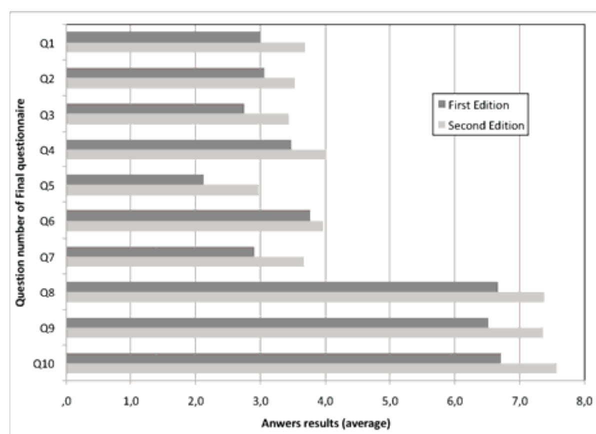


Figure 5. Final questionnaire results evolution.

On the one hand, the information observed from standard deviation may be considered in a revision of questionnaires, as an indicator of which questions must be adjusted, because it is possible that the students did not understand it. On the other hand, a standard deviation high in one question shows some discrepancies with the average answer, and could be studied with more attention.

Figure 5 shows the average values of final questionnaire for both editions. The students answer questions Q1 to Q7 with a maximum value of 5, while the questions Q8 to Q10 can be valuated until 10. From chart of Figure 5, some comments can be obtained:

- All results show a positive impact of the first edition on the second edition results, increasing the first edition results.
- The impact of writing activity has increased the student motivation from one year to the next, as shown Q1 and Q2 answer results. In fact, the importance of this activity, as perceived by student has increased too, see results of question Q3.
- A majority of students believe that this activity has helped to improve the results in the subject, see Q4.
- The importance of comparison has decreased, so the students seen to tolerate better the process of external review, or the publication of their works.
- Although the writing activity has not been considered as a hard work, finally, at the end of the process with the review, the students valuate the task developed as a hard work (question Q7).
- The students' self-esteem is increased, because they are feeling that they are capable to do similar activities again (question Q8).
- The effort of writing in a technical manner is valued positively by the students, while the motivation or expectation to see its paper published in the journal is maintained at the same level as at the beginning of the activity.

- TABLE 4. FINAL QUESTIONNAIRE STATISTICS

	Average		*Standard deviation*	
Editions	***First***	***Second***	***First***	***Second***
Q1	3.0	3.7	1.0	0.9
Q2	3.1	3.5	1.1	0.7
Q3	2.7	3.4	1.1	1.1
Q4	3.5	4.0	0.9	0.6
Q5	2.1	3.0	1.0	0.9
Q6	3.8	4.0	0.9	0.7
Q7	2.9	3.7	1.0	0.9
Q8	6.7	7.4	1.6	0.7
Q9	6.5	7.4	1.2	0.9
Q10	6.7	7.6	2.4	1.4

In Table 4, it has been collected the average and standard deviation of the final questionnaire answers. In this case, only question Q3 maintains a standard deviation high in both editions. The high number of questions with high standard deviation during the first edition could be explained taking into account that the students did not have any copy of the journal, so the activity goals were not clear to all students involved in it.

CONCLUSIONS

This study has been developed in two years and has tried to evaluate the impact on the student's motivation of public recognition using a writing activity. In technical courses there are a lot of students' activities or degree projects which may be used to create a publication. In fact, the process of publication is an educational process, where the own knowledge is compared, shared and discussed with colleges.

The proposed study has demonstrated how the process of writing, reviewing and publishing may help to improve the motivation of students in different areas: personal motivation, implication with the subject activities or as a reference for future students. The activity has been valuated positively by students in both editions, as it is observed in the final results.

The writing process may be a useful educational process, not just for the authors of the best papers, but also for all the students involved in the review process.

The impact on future degree project reports is not evaluated yet, but we believe that, in general, the writing skills will be improved, and this kind of activities allows promotion of non-classroom activities, which may impact in the same way in all courses. Perhaps, theses kind of activities are necessary to learn socio-professional capacities in future engineer courses.

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Session 04A Area 4: Learning Models - Learning tools

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Freudenthal, Eric; Ogrey, Alexandria N.
University of Texas at El Paso (United States of America)

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Benlloch-Dualde, José-Vicente; Buendía, Félix; Cano, Juan Carlos
Technical University of Valencia-UPV (Spain)

M-learning tools on distance education
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Teaching Digital and Analog Modulation to Undergradute Information Technology Students Using Matlab and Simulink
Boulmalf, Mohammed; Lakas, Abderrahmane; Semmar, Yasser; Shuaib, Khaled
Al Khwayn University in Ifrane (Morocco); Qatar University (Qatar); UAE University (United Arab Emirates)

A computational introduction to STEM studies

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Abstract— **We report on the content and early evaluation of a new introductory programming course "Media Propelled Computational Thinking," (abbreviated MPCT and pronounced iMPaCT). MPCT is integrated into a freshman-level program designed for under-prepared students with interests in a STEM discipline. It is intended to reduce attrition rates by fostering student intuition in, appreciation of, and confidence about basic pre-calculus concepts.**

The MPCT curriculum is problem-driven, with analytical challenge exercises that are intended to motivate inquiry and to illustrate the reasoning used in the STEM professions Preliminary evaluation results are encouraging – students from a wide range of academic majors found MPCT engaging, and report that the course conveyed insight, and decreased anxiety about foundational mathematical concepts.

Keywords-component; introductory computing curriculum, CS0, MPCT, entering students program, CCLI, CPATH.

I. INTRODUCTION

We report on the content and early evaluation of an introductory programming course titled "Media-Propelled Computational Thinking" (MPCT) [5] that is intended to retain students in STEM disciplines by strengthening their understandings of pre-calculus concepts.

At UTEP, MPCT has evolved into variants taught with the introductions to several of the STEM subjects. The original version was integrated into some of the Entering Students Programs (ESP) [4] attended by entering freshmen at the University of Texas at El Paso, a primarily Hispanic-Serving Institution (HSI) serving an economically disadvantaged bi-national urban area on the US-Mexico border. The ESP course is designed to help students develop the skills necessary for academic success, and to assist students in career selection. Consequently, half of the ESP course addresses issues such as study, note-taking, presentation, writing skills, and career guidance. The other half features a technical content module such as MPCT. Its purpose is to present an engaging broad-brush perspective about learning technical content.

Introductory courses for technical disciplines such as computer science can only provide a limited set of activities. One of the main challenges we faced in the design of MPCT was how to use our very limited classroom time in a way that is not only engaging, but that first and foremost improves student readiness for calculus and the challenges of mathematical reasoning. At UTEP, students often have to spend four semesters in remedial and background classes before enrolling in a first course in a STEM major. Consequently, we needed a half-course that could enhance student interest in CS, while simultaneously providing enough mathematical intuition to improve student retention in the high-attrition STEM majors. Trial courses based on outside programs identified some engaging curricula -- especially for students interested in art or in the use of applications to solve specific types of problems -- but none of the programs seemed to have enough focus on pre-calculus mathematics concepts backed by hands-on programming. So we designed our own course, which turned out to require far more work than we had anticipated.

Section II presents the main pedagogical concerns that guided the overall design of MPCT.

The need for an easy-to-use programming environment was also of great concern, since students need to focus most of their time on analytical tasks and algorithm design, and not program syntax. Likewise, we realized that typical programming projects in MPCT had to be very short. Typical assignments are solved with four to ten lines of Python code that includes numerical iteration controlled by for-range statements. To provide students with visceral understandings of program behavior, the output is generally graphical, and involves the direct manipulation of pixels within an RGB image plotted in Cartesian coordinates. Section III presents some of the constructs used to minimize the syntactic difficulties.

The progression of concepts and projects is presented in Section IV. Programming fundamentals are introduced and exercised within lab assignments during the first couple of weeks of class in the context of graphical manipulation such as such as the use of nested for-range statements to enumerate the coordinates of pixels within geometric objects. Subsequent labs first examine the plotting of simple mathematical functions, which are later extended to explore the simulation and mathematical simulation of familiar physical phenomena such as ballistics and resonance.

Section V mentions the adaptation of this education program for other courses at UTEP, and Section VI presents ongoing efforts to evaluate MPCT. A preliminary study indicates increased confidence and interest in pursuing

STEM studies despite MPCT's lack of socially motivated context. Our research plans include a longitudinal study of academic progress that examines the success of students who pursue STEM studies after attending MPCT.

II. THE PEDAGOGICAL APPROACH

MPCT's design is motivated, in part, by observations that deficiencies in, and anxieties about mathematics cause many students to avoid computer science and other STEM disciplines, and are likewise responsible for much of the attrition from these programs. Thus, the key question in designing MPCT is how to foster better mathematics intuition, and how to instill these understandings in an engaging (and hopefully enduring) way. Of course, the results to date, though encouraging, are only preliminary, and much more needs to be done to see if the basic approach can be extended to encompass a more substantial curriculum. Nevertheless, it is not too soon to communicate some preliminary conclusions -- especially when learned from mistakes and occasional failures.

In retrospect, this project has benefitted from a small number of critical design principles. Some of the most important are listed below.

1) Minimize syntactic overload.

Students need to spend most of their time mastering concepts and developing intuition. The syntax of object oriented programming and excessive type declarations can be very time-consuming for beginners.

2) Use a sequence of exercises that present a coherent progression of worthwhile projects.

Since MPCT is intended to use computation to strengthen mathematical reasoning, we designed exercises (coupled with interesting applications) that illustrate increasingly advanced principles in pre-calculus and calculus. Section IV covers the sequence in detail. We also selected problems that are in some sense representative of the issues faced by practicing STEM professionals.

3) Hands-on computing and a see-for-yourself approach to learning is unlikely to succeed unless each inquiry-based exercise is designed with the utmost of care, and tested to ensure that the outcomes match the intentions.

The first version of MPCT used an early exercise that asked students to the graph lines y=ax+b and experiment with the parameter a to see what happens. To our surprise, the overall lesson failed to instill a sound understanding of slope. A revised exercise sequenced through smaller, more carefully structured steps: Fill row 13 of an array; Plot the line y=13, Now treat y as a running sum that begins at 13, and grows by the constant 0.1 from x-value to x-value. Now change the growth constant from 0.1 to 0.5. Here the primitive was slope, and students quickly grasped the idea that straight lines and constant slope (growth) were equivalent. More importantly, they displayed a solid understanding of slopes, and the progression to parabolas based on constant incrementation of the growth rate (slope) was much easier to teach.

III. MINIMIZING EMPAHSIS ON SYNTAX

Programming techniques in early courses should be chosen to minimize cognitive load while maximizing pedagogical value. The focusing of MPCT to introductory computation included a significant reevaluation of the programming interfaces used to support coursework. The original programming interface used the rich object oriented (OO) Java AWT toolbox exposed by the programming framework of [1]. With this approach, even the design of extremely simple algorithms requires fairly complex access code before anything can be programmed. Consequently, the *conceptual* content embedded within our introductory programming lessons were often overwhelmed by the mainly *clerical* task of managing the access and manipulation abstractions for pixels in Java.

This motivated our development of an alternative shallow Raster class described in Figure 1. All pixel accesses explicitly specify row-column addresses. Thus, a pixel location is just a (row ,column) pair of integers represented using a native Python tuple (vector) type, and a pixel color is just a red-green-blue tuple. Algorithms that visit all pixels in a rectangular region can be programmed by a pair of nested loops. As reported in [5], students have little trouble understanding nested iteration in this context.

Constructors
- `Raster((numCols, numRows))`
- `Raster((filename))`

Accessors
Origin is in lower-left corner
Parameters & return values are tuples
- `r, g, b = getRGB((col, row))`
- `setRGB((col, row), (r, g, b))`

Controls
- `setAutoRepaint(state)`
  redraw on every access (default true)
- `setIgnoreOutOfRange(state)`
  silently ignore out-of-range accesses (default true)
- `width, height = getWidthHeight()`
  returns raster geometry

Actions
- `write(filename)`
  save to file
- `repaint()`
  redraw now

Figure 1. Public interface to Raster class

The course begins with by presenting simple code that draws dots and lines. Students adapt them to draw rectangles, triangles, trapezoids and parallelograms by the end of the second class. Figure 2 presents a program sometimes examined within the first two weeks of class that dramatically modifies a familiar cartoon image. The example was selected to illustrate low-overhead programming – *the code does not even require a function definition.*

In order to facilitate projects that plot mathematical functions and leverage students' incoming knowledge, Raster's origin is located in the lower-left corner, and thus column-row addressing directly mimics x-y coordinates within the first quadrant of a Cartesian plane.

```
url = "http:….jpg"
p = Raster(url)
green = (0, 255, 0)
cols,rows =  p.getWidthHeight()
 for col in range (cols):
  for row in range (rows):
     r,g,b = p.getRGB((x,y))
     if r<40 and g<40 and b<40:
        p.setRGB((col,row), green)
```

Figure 2. Program to recolor dark pixels

In short, the simplifications in the necessary code allow the class time to focus on the logic and the algorithms rather than object-oriented hierarchies that provide abstractions ill suited to the problem being addressed. Later projects require the plotting of functions with negative range that are (deliberately) inconvenient to represent with Raster's origin, which is located in the image's lower-left corner. MPCT pragmatically utilizes this inconvenience to motivate the introduction of a `PosNegGraph` class that extends `Raster`. Both `Raster` and `PosNegGraph` are referenced by examples in this paper.

The next section summarizes the curriculum, including example problems in the newly developed modules on mechanical resonance and coupling, and planned extensions of MPCT's pedagogical approach to other courses. Finally, we report on our in-progress course evaluation and adaptations to the evaluation plan in response to MPCT's evolved focus.

IV. Topic Sequence

Figure 1 presents a flowchart of course modules and prerequisite dependencies. A strong–inter-module dependency is represented by a solid line; and a weaker dependency (indicated by a dotted line) indicate an alternate path that permits a course to move more quickly at the cost of removing a particularly engaging presentation of a key concept.

Initial programming exercises are sufficiently short to be conveniently typed directed to the interpreter. The first exercises contain no explicit arithmetic operations, which are gradually introduced to implement increasingly sophisticated computation. The difficulty of reliably typing more advanced programs motivates their storage within files.

The overall program is designed to foster experimentation and to encourage students to review fundamental concepts in algebra and geometry in a way where motivated understanding leads to successful program-generated displays.

For example, A.2 provides a preferred first exposure to nested looping that provides opportunity for students to play with both column- and row- major filling of simple polygons in a dramatic and motivated context. In A.3, students apply their newly gained knowledge of nested iteration to the filling of a rectangular region in A.3, which uses nested looping over both columns and rows to visit every pixel within a rectangular region.

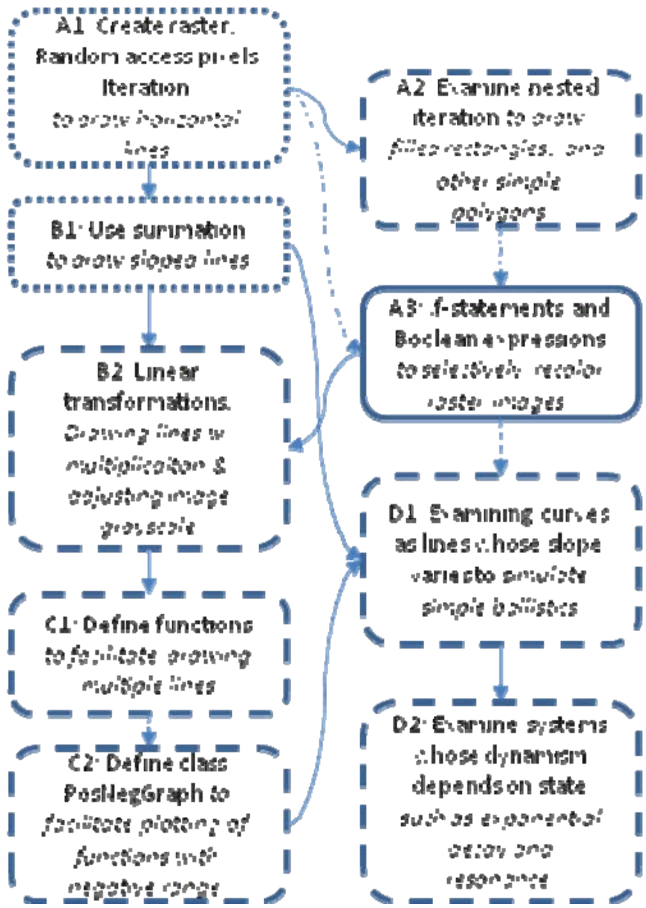


Figure 3. Linkages among course modules

A. *Programming Basics*

In a manner analogous to an immersive language course, students begin to 'converse' in Jython using only three statements to draw a multitude of geometric objects:

- `Raster(size)` – Used to "construct" a computer image:
- `setRGB(pos, color)` – Used to draw a dot:
- `for loops` - Used for iteration.

As described below, these commands allow students to:

- Draw lines as a sequence of dots stacked in a row.
- Draw boxes as a sequence of lines stacked in a column
- Draw triangles, parallelograms, and trapezoids by deriving the inner loop's range from the outer loop's iteration variable.

Module A.1: Create raster, random access pixels, iteration to draw horizontal lines: This introductory lesson exploits Python's interactive mode to permit students to issue single commands to create and manipulate a raster image (represented as a Raster object) and "draw" upon through the column-row selection of individual pixels that are conveniently represented using Python's native tuple (vector) type. The clerical challenge of reliably typing sequences of commands first motivates the storage of a sequence of commands within a file in a manner can be easily repaired or reused using copy/paste. Finally, iteration is presented as a convenient and intuitive solution to the challenge of repeating a single command multiple times while varying a single parameter in order to draw horizontal or vertical lines as is illustrated in the top row of Figure 4.

```
pic = Raster((80,80))
for col in range(20,60):
  pic.setRGB((col, 15), green)

pic = Raster((80,80))
for col in range(20,60):
  for row in range(40, 50):
    pic.setRGB((col, row), green)

pic = Raster((80,80))
for col in range(20,60):
  for row in range(20, col):
    pic.setRGB((col, row), green))
```

Figure 4. Exploration of iteration

Module A.2: Examine nested iteration to draw filled rectangles, and other simple polygons: As illustrated in the lower two rows of Figure 4, A.2 exploits students' familiarity with direct pixel manipulation and iteration presented in A.1 to provide students with an engaging opportunity to playfully tinker with tiny programs that generate filled geometric forms. A.2's engaging sequence of exercises first introduce students to the nesting of loops as an intuitive and simplifyin approach to the clerical challenge of enumerating the location of every pixel within rectangular region and then provide an opportunity to develop intuition about inter-loop interactions.

For example, the first project traverses every pixel within a rectangular region in column-major order, and its immediate successor challenge students to fill the same region in row-major order. Conceptual errors result in easily understood graphical results that are amenable to student analysis and repair. A.2's scope can be modulated by available time and desired learning outcome. Optional lessons examine interactions between inner and outer iteration bounds in order to draw non-rectilinear forms such as triangles, parallelograms, and trapezoids and manipulate iteration stride to enable the drawing of striped patterns. Should the learning priorities include only a superficial understanding of iteration, A.2 can be omitted entirely and the topic can instead be briefly presented in the context of A.3.

Module A.3: If-statements, relational, and boolean operators to selectively recolor raster images: As illustrated above in Figure 2, this lesson uses nested iteration and exploits conditional expressions including relational, Boolean, and grouping operators to conditionally change the color of pixels within a rectangular image. Earlier modules used intuitively named pre-defined constants (e.g. "green") to represent colors. A.3 exposes the graphical system's underlying representation of color as red-green-blue tuples. A raster image is initialized from a jpeg explicity obtained from "the web" using HTTP.

Each pixel location within the rectangular (raster) image is systematically visited using nested iteration. Each pixel's red-green-blue vector is obtained and unpacked into its components using a single getRGB method. An if-statement that contains relational and Boolean operators controls whether the pixel's color-vector is overwritten. Projects challenge students to both experiment with the creation of conditional expressions that select alternate colors and the specification of vectors representing desired alternate colors. Finally, students are exposed to the complexity of automating the detection of forms easily recognized by the human vision system. Optional projects examine simple image processing techniques such as blurring that provide insight into convolutional operations.

B. *Linear systems*

Module B.1: Use of summation to draw sloped lines and the computation of slope: This module examines the nature of linear systems. As illustrated by the top two images and programs from Figure 5, initial projects extend the concept of iteration introduced to draw horizontal lines in A.1 to instead draw sloped lines using summation. A row variable is initialized at column zero. A constant "step size" value is repeatedly summed into the row variable increasing its value at a linear rate that is graphically depicted. Students characterize the effect of various step sizes and initial row values. Later exercises lead students to derive the meaning of their generalization as slope and y-intercept.

As illustrated by the image and program at the bottom of Figure 5, students are subsequently challenged to draw lines that connect designated points (say, to draw a geometric shape). To do this, students must derive the step size from the desired change in row and column using division. We observe that most attending the class can parrot "y=mx+b" as an equation for a line, but nonetheless initially have trouble computing step size; even math-phobic students enrolled in non-STEM programs and are visibly delighted when they derive an approach to determining step size (slope) using division.

Module B.2: Linear transformations: Drawing lines with multiplication and adjusting image grayscale. This module challenges students to generalize their understanding of line generation to the linear projection from an input variable to a dependent output variable. Early projects examine the concept and utility of computing a y-intercept in order to easily compute the row corresponding to any column.

```
pic = Raster((80,80))
…
row = 15
for col in range(0,pic.width):
  pic.setRGB((col, row), green)
```

```
row, step = 15, 0.5
for col in range(0,pic.width):
  pic.setRGB((col, row), green)
  row = row + 1
```

```
first, last = (10, 10), (70, 50)
run = last[0]-first[0]
rise = last[1]-first[1]
step, row = float(rise)/run, first[1]
for col in range(first[0], last[0]):
    pic.setRGB((col, row), green)
    row += step
```

Figure 5. Exploration of line drawing

A particularly motivational project from this lesson examines the grayscale correction of pictures with limited dynamic range. Following a discovery-learning model, students are initially challenged to “improve” the picture’s contrast without guidance Typically students will suggest appliying either linear scaling or constant offsets.

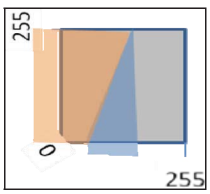
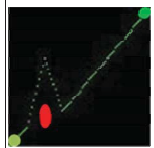


Figure 6. Expansion of image grayscale

Figure 6, illustrates a composite approach that applies a linear transform that projects the input image’s limited grayscale to a full 0…255 range. The challenge of correctly displaying a negative image permits students to explore the computation of inverse relationships.

C. *Managing complexity using language features*

Module C.1: Defining functions to facilitate drawing multiple lines: Functions are introduced as an approach to reduce complexity through the creation of reusable code fragments. As illustrated in Figure 7, students are challenged to write programs that draw a path using line segments that connected designated start and end points and avoid colored obstacles. Rather than focusing on the path problem, this module provides opportunities to first practice the application of computing slope. Observe that, the body of drawline appearing in Figure 7 is identical to the program at the bottom of Figure 5. In this manner, reduction of the program complexity is achieved by drawing multiple lines with multiple calls to a single function rather than the insertion of repeated code fragments.



```
def drawline(first, last)
  run = last[0]-first[0]
  rise = last[1]-first[1]
  step, row = float(rise)/run, first[1]
  for col in range(first[0], last[0]):
    pic.setRGB((col, row), green)
    row += step
```

Figure 7. Maze and function from C.1

Module C.2: A user-defined class that facilitates plotting of functions with negative range: The linear systems examined previously only have non-negative range. In this module, students are encouraged to examine negative range by translating the image through the adding of a constant to the row value. The repetitive task of translating the image to examine the negative range motivates the examination of a user-defined class that centers and draws the X-axis. As illustrated by Figure 8, the easily understood PosNegGraph class conveniently translates the origin to the middle of the left edge.

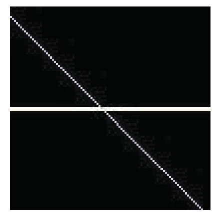


Figure 8. Illustration of PosNegGraph plot

D. *Non-linear systems*

To ensure that students are not intimidated by unfamiliar mathematical abstractions, we prefer to first introduce evolving processes using the simplest-possible generators, and then to guide students into discovering algebraic simplifications they are fully prepared to understand.

The topics sequence through increasingly complex computational themes where all of the physical modeling is based on rates of change or summations (as opposed to integration).

Lab exercises examining non-linear systems extend the summation techniques previously examined to simulate the dynamics of familiar physical phenomena. Exercises mimic the familiar phenomenon of ball bounce and spring resonance, which are frequently poorly understood, even by students who have completed a semester of college physics [6].

Finite differences are computed at each time step and are summed into system state. Longitudinal studies are being conducted to determine if cohorts of students who are first exposed to these concepts through simulation have improved academic success in subsequent courses that examine the same phenomena using calculus.

For problems in mathematics and physics, we endeavor to minimize the level of outside knowledge required, and prefer show how processes evolve at an intuitive level and where incremental changes in the process state can be explained in physical and computational terms -- much like [7].

Math-centric programming projects generally begin with an exploration of the effects of rates-of-change. Afterwards, students are guided to reduce the already familiar summation problems (implicitly a recursive formulation) to closed form.

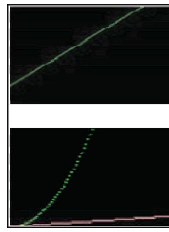
D.1: Examining curves as lines whose slope varies to simulate simple ballistics: Boolean expressions and conditional statements (taught in A.3) should be taught if the simulation of a ball bounce is included in the lesson. The instructor leads a discussion about the similarities and differences between lines and curves and elicits an observation that a curve's slope must vary. Students add the rate variable, and begin to experiment with drawing curves.

The main study concerns curves whose slope changes linearly as shown in the parabola in the bottom Figure 9. Once sufficient time has been spent experimenting with drawing curves, students begin to apply what they have learned to simulating familiar phenomena such as ballistics and ball bounce.

In ballistic problems, objects are accelerated only by gravity. Their trajectory is parabolic. The slope of their trajectory with respect to time corresponds to velocity. The slope of their velocity with respect to time corresponds to acceleration. The mapping of trajectories to parabolas is straightforward: slope corresponds to velocity, and the slope's constant rate of change maps to acceleration. Students first simulate a single "toss," and then are challenged to simulate a bounce as an inelastic collision with the ground, where at each bounce, velocity is reduced by 20%. This leads to an exponential decay in the maximum height achieved after each bounce. The `parabola` program's overlaid plot of position and velocity illustrates both continuous and discontinuous evolution of physical parameters.

As illustrated in Figure 10, students are able to easily examine the effects of varying initial conditions including examples where the slope and rate have different and same initial signs. Finally, the relationship between parabolas and quadratic functions are made concrete through geometric proofs such as depicted in Figure 11.

D.2: Examination of systems whose dynamism depends on state such as exponential decay and resonance. It is interesting that upperclassmen who have attended multiple courses in Calculus are enthralled by the progressive computation of exponential decay illustrated in Figure 12 that could easily be understood by a freshman if presented in an accessible context. We observe that the spring resonator of Figure 13 is accessible to students attending a first course in mechanics. The electrical resonator of Figure 13 is incorporated in an introductory programming course offered to students in electrical engineering in the Spring of 2010 that incorporates the pedagogy of MPCT.



```
row, step = 15, 0.5
for col in range(0,pic.width):
  pic.setRGB((col, row), green)
  row = row + 1

row = step = 0
rate = 0.1
for col in range(0,pic.width):
  pic.setRGB((col, row), green)
  pic.setRGB((col, step), pink)
  row += step
  step += rate
```

Figure 9. Progression from lines to curves

```
def bounce(height=50, speed=0, accel = -0.1):
  pic = PosNegGraph((100, 75))
  for time in range(0,pic.width):
    pic.setRGB((time, height), green)
    pic.setRGB((time, speed), pink)
    height += speed; speed += accel
    if height < 0 and speed < 0:
      speed = -0.8 * speed
```

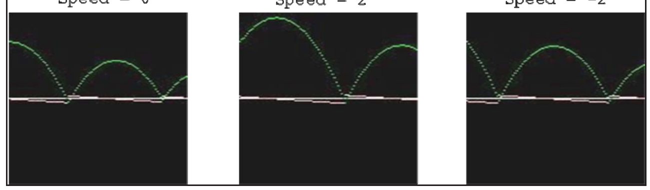


Figure 10. Ballistic simulations

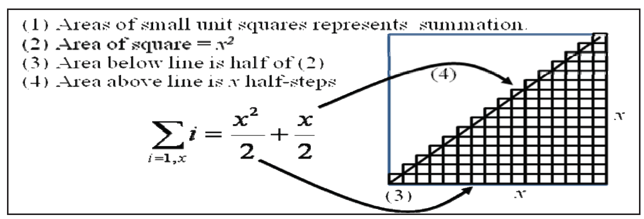
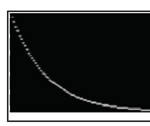


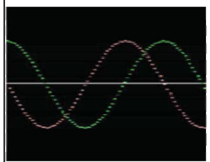
Figure 11.
Graphical depiction of linear sums in closed form as a quadratic function



```
i = Raster((80, 80))
row = 80
for col in range(0, 80):
  i.setRGB((col, row), white)
  row = row * 0.95
```

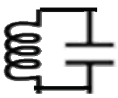
Figure 12. Exponential decay

MPCT completes with an example of coupled resonance illustrating the principle underlying an opera singers' wine-glass shattering trick and the catastrophic failure of the Tacoma Narrows bridge (see Figure 3) in 1940 and the crashes of several Lockheed Electras around 1960.



```
i = PosNegGraph()
pos = 45; speed = 0
springConst = 0.01
deltaT= 0.1
mass = 0.01
for x in range(0, i.width):
  i.setRGB((x, pos), green)
  i.setRGB((x, speed), pink)
  force = -pos * springConst
  accel = force / mass
  speed += accel * deltaT
  pos += speed * deltaT
```

Figure 13. Simple mechanical resonator



```
img = PosNegGraph((300, 100))
V, I = 0, 50.0e-3    # initial conditions
C, L = 1e-9, 1e-3    # farad, henry
for x in range(0, img.width):
  img.setRGB((x, 1000*I), white) # fs=100ma
  img.setRGB((x, V), green)
  dv = (I/C) * dt
  di = -(V/L) * dt
  V = V + dv
  I = I + di
```

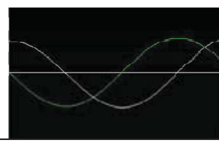


Figure 14. Electrical resonator

MPCT completes with an example of coupled resonance illustrating the principle underlying an opera singers' wine-glass shattering trick and the catastrophic failure of the Tacoma Narrows bridge (see **Photo image courtesy of Ed Elliott www.camerashoptacoma.com. All rights reserved. [8]**

Figure 15) in 1940 and the crashes of several Lockheed Electras around 1960.

Figure 16 illustrates the result of an advanced project that examines coupling when both the oscillator and resonator are tuned to the same frequency. Like the catastrophic failures enumerated above, this resonator quickly accumulates energy from the oscillator.

Photo image courtesy of Ed Elliott www.camerashoptacoma.com. All rights reserved. [8]

Figure 15. The Tacoma Narrows Bridge

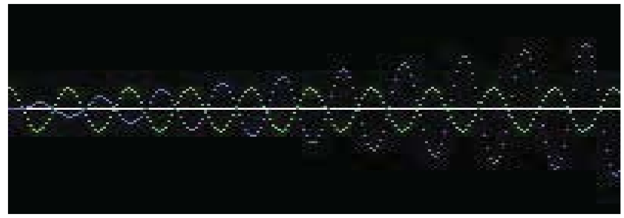


Figure 16. Simulation of coupled resonance

V. Extensions to Other Courses

A new introductory course titled "Computation for Science and Engineering" in computational science intended for upper-division students of STEM disciplines that traditionally do not include computation such as biology, geology, finance, and math is planned for Spring 2010. This course will introduce programming using examples from MPCT, and then will proceed to implement simulations modeling more dynamic systems in which a sudden action could change the "normal" or expected behavior such as production-consumer markets, investment valuation, predator-prey models, and biological processes.

Two other pilots are beginning in Spring 2010.: A section of an introductory programming course offered to students enrolled in Electrical Engineering will be taught using MPCT's pedagogical approach and will include projects that simulate dynamism in electrical systems. A section of a statistics course attended by students of psychology will also include elements from MPCT with the expectation that the process of constructing simulators of stochastic systems will assist in students' understanding of coupled and independent random processes.

We are also adapting this approach of motivating math from concrete problems to the teaching of algorithms. There, the objective is to use specific problems as a vehicle for teaching algorithms as general methods that can be adapted to solve related problems of interest. We find that by teaching algorithmic schemas to solve "purified" problems, students can follow the reasoning far more easily and can sometimes develop the computational idea themselves. As in MPCT, the layered elaborations are introduced step-by-step to solve increasingly complex problems as described in [9].

VI. Evaluation

More than half of the students entering UTEP intending to study CS are not "calculus ready," as required for CS1. First-attempt pass rates for CS-1 range from 50 to 70%, which surely contributes both to student time-to-graduation and attrition. Thus the need for intervention is clear. During the development of MPCT, several variants of Media Programming were offered at UTEP. In all versions, almost all students demonstrated proficiency at basic programming concepts and passed.

UTEP is a member of the Computing Alliance of Hispanic Institutions (CAHSI), which is evaluating various CS-zero courses offered at multiple institutions serving predominantly Hispanic populations of students. These evaluations include intermittent classroom observations and both pre- and post-course surveys examining preparation, social context, student engagement with the course, interest in further study of computation, and success in subsequent coursework.

In their 2008 report, the CAHSI evaluator measured high levels of both interest and confidence [10] among entering students prior to attending the course, though less than 20% had previously programmed. Post-course surveys of students attending the precursor courses indicate that 25% of the students were not motivated to continue studies related to computer science. This is likely a positive result if the course helped students correct unrealistic expectations about computer science early in their academic careers.

Students who attended a variety of CS-0s (including Media Programming at UTEP and Alice at other institutions) had similar passing rates that were similar to the general population. The mathematically-oriented revisions to MPCT have required several semesters of development and have only recently been implemented – hence no longitudinal data is available yet.

Entering STEM students attended MPCT during the Fall semester of 2008, and non-STEM students attended distinct sections during both the Fall and Spring semesters. The mathematics included in the section was first offered Spring 2009, and therefore was only attended by non-STEM students. A post-course survey of the Spring 2009 non-STEM cohort examined changes in (1) perceptions of knowledge and understandings of key concepts, (2) perceptions of mathematics' relevance to 'real life' scenarios, and (3) attitudes toward learning math concepts in the context of programming.

As described in [11], the preliminary findings from the non-STEM section are encouraging. Although the sample size was too small to draw reliable conclusions, they reflect the instructors' observations of student motivation and engagement. Survey results indicate shifts from low level to higher levels of understanding math concepts introduced in MPCT, positive attitude toward MPCT structure and its intended objectives, and highly favorable perceptions of MPCT's relevance to real-life applications. We expect statistically reliable results from the Fall 2009 cohort, which is much larger, containing more than sixty pre-STEM and twenty non-STEM students.

During the Spring 2009 term, the evaluation was broadened to include instruments that examine changes in interest, self-efficacy and competence related to mathematics. Several open-ended essay questions were included in order to guide the selection of relevant questions for the intended Fall evaluation.

Pre-survey results indicate that in addition to high confidence in programming their programming skill, students have high confidence in their math skills that are inconsistent with their performance in class.

Our longitudinal evaluation will be broadened to also compare the academic success of students in subsequent math courses with the academic success of students who do not attend MPCT.

VII. Conclusion

Continuing evaluation of introductory programming offerings at UTEP targeting pre-STEM students have motivated evolutions in curriculum, course objectives, and evaluation strategies. Interestingly, the resulting course, MPCT, which engages students in a "computational reasoning," integrates both programming and mathematics, is engaging to both pre-STEM and non-STEM students with weak math skills. Results from early evaluation efforts are encouraging and have lead to refinements in evaluation strategy that mirror the course's evolution.

VIII. Acknowledgement

This report is based on work supported by the National Science Foundation through grants CNS-0540592, IIS-0829683, and DUE-0717877 and gifts from Texas Instruments Inc. and Calculex, Inc.. Any opinions, findings, and conclusions or recommendations expressed in the paper are those of the authors and do not necessarily reflect the views of the NSF or other funders.

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A Tablet PC-Based Teaching Approach using Conceptual Maps

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Abstract— **There are clear evidences that technology can drive major positive changes in the classroom addressing problems associated with traditional lecture-based pedagogy. In particular, the flexibility of Tablet PCs and digital ink has the potential to achieve a wide range of educational goals and promote a more dynamic classroom environment. However, as the possibilities of these educational technologies grow, it seems necessary to consider their role by conceptualizing the knowledge they provide. In this work we propose a teaching approach based on the use of conceptual maps to generate instructor guidelines for Tablet PC-based courses. Our approach combines the instructional domain with the technological one in order to offer practical guidelines to design and develop both lecture materials and active learning experiences, providing a systematic and flexible way to guide the teaching process in a Tablet PC-based learning scenarios. We present a case study on how to implement the approach in a first-year Computer Engineering course reporting the introduction of the Tablet PC in this educational setting.**

Keywords- Tablet PC; Digital Ink; Conceptual Maps; Instructional Design.

I. Introduction

The widespread adoption of slides displayed with a digital data projector has supposed an unquestionable technological change in the classroom. However, it has no essentially modified the lecture model of instruction, which is still prevalent in many of our Computer Engineering (CE) undergraduate courses. It is often difficult to maintain concentration of students for the entire 2-hour lecture sessions, especially when there is a lack of variety in the teaching method. Stuart and Rutherford [1] assessed students' concentration during a didactic lecture and found that ''concentration rose to maximum at 10-15 min. and then fell steadily until the end of the lecture''.

One of the latest trends in instructional technology is the use of Tablet PCs in the classroom. In recent years, Tablet PCs are making its headway into classroom instruction at every level, from primary and secondary school, to higher education. In fact some recognized institutions, such as Virginia Tech, have adopted, since 2006, a mandatory program requiring all first-year students in College of Eng. to own a Tablet PC [2].

Recent research demonstrates obvious advantages of using Tablet PCs in higher education. In fact, there are clear evidences that technology can drive major positive changes in the classroom, addressing problems associated with traditional lecture-based pedagogy [3].

However, we think that any random implementation of educational technology has a low probability of success and widespread adoption. We consider that clear guidelines are required to develop and deploy such new technology settings. As the number and possibilities of Tablet PC and pen-based technology grow, it seems necessary to consider the role of these educational technologies by conceptualizing the knowledge they provide. There are different tools to represent and organize these knowledge items and we have selected conceptual maps [4] as one of the more flexible and powerful techniques to support this process. Concept maps are graphical tools for organizing and representing knowledge. They include concepts and relationships and their use permits modeling mental trees of assimilated concepts to a simple format.

In this work we propose TAGGE (*Teacher Assistance Guideline Generation Engine*), as a teaching approach to generate instructor guidelines for preparing interactive face-to-face courses supported by technology. Based on the learning requirements of a specific educational setting, TAGGE uses conceptual maps to model the instructional domain and the technology domain in order to provide clear teaching guidelines, i.e., the outputs of our approach. These guidelines will then be used by instructors to adapt traditional courses to an active learning technology-based course. The main idea behind TAGGE is, on the one hand, the conceptualization of the instructional and technological domains using conceptual maps and, on the other hand, to relate the instructional domain to the technological issues in order to propose the teaching guidelines.

This paper is organized as follows. Section II reviews the related works using Tablet PCs and conceptual maps to enhance the learning process. Section III presents TAGGE, our teaching approach. Section IV describes the conceptualization of an educational setting example. Section V presents the teaching guidelines offered by the TAGGE approach in this particular context. Section VI describes the teaching context of our case study and presents some preliminary results. Finally, Section VII presents some concluding remarks.

II. Related work

In this section we first present some of the most outstanding works using Tablet PC to enhance learning and to promote student engagement. After that we review some of the fields where conceptual maps have been applied.

A. Using Tablet PCs on Education

The advantages of using Tablet PCs in a classroom have been reported by several studies in the last few years. In [5] authors used the Tablet PC in an upper level Electrical Engineering course for both content development and presentation. Tablet PC was also used in [6] for several undergraduate engineering courses, which clearly showed how it facilitates collaborative and active learning, allowing the instructor to spend more time on explaining concepts rather than drawing figures. In [7] classroom instruction using a Tablet PC with standard PowerPoint presentation and whiteboard are compared. The authors reported that Tablet PC-based class presentation showed better attention rate and better comprehension of the material. Tablet PCs are also being increasingly used in secondary school where the overall learning process is greatly improved if they use Tablet PCs [8].

In terms of instructional tools, *Classroom Presenter* [9], developed by the Univ. of Washington, has the ability to enhance the usage of PowerPoint-based slides, allowing students to communicate among themselves and the instructor in real time. *DyKnow* software [10], which has two interoperable programs within it, *Monitor* and *Vision*, is another interesting example. *Monitor* enables the instructor to monitor and/or block unauthorized student computer activities, while *Vision*, fosters interaction through collaborative note taking, student response tools, content replay, and anywhere, anytime access. *WriteOn* [11] is another tool, which can be used together with Tablet PCs to allow annotating on top of any application visible on the Tablet screen.

B. Applying conceptual maps

II. Concept maps have been around for quite some time, and their principles are deeply rooted on well-known learning theories. Their adoption sought to offer an Ausubelian perspective of the knowledge acquired [12] by allowing to externalize mental trees of assimilated concepts to a simple format. In terms of learning approaches, concept maps offer the evaluator great insight and help at detecting misunderstandings and flaws in the learning process strategy. Concept maps were first proposed by Novak [4] a few decades ago. They consist of a very flexible structure that allows users to create meaningful relationships between key concepts so as to improve the processes of learning and knowledge acquisition in general. Since their invention, they have received much attention from researchers and experts worldwide. In fact, concept maps have been used in various areas of knowledge with heterogeneous purposes such as creating cross-language tools [13], thereby simplifying concept translation between different languages, as a tool to enhance web searches [14], in the evaluation process in Computer Engineering Undergraduate Courses using objective metrics[15], or even to improve the public outreach of the Mars exploration mission[16].

In this work we used concept maps in order to model the instructional learning domain and the Tablet-PC technological domain, and thus generating teaching guidelines in Tablet PC-based courses.

III. TAGGE: OUR TEACHING APPROACH

This section introduces TAGGE, our approach to generate teaching guidelines for technology-supported courses. This approach is based on modeling the knowledge items about instructional and technology issues that are part of a specific course. This conceptualizing process will enable the guideline generation in a more systematic and flexible way.

Fig. 1 shows the conceptual framework of TAGGE. It takes the learning requirements attached to a specific course as inputs (e.g., the learning general needs, the learner profile, or the course subject features) and processes them to obtain the guidelines to assist instructors in a particular learning scenario. The basic under TAGGE is the conceptualization of the instructional and technological issues for a given learning scenario (e.g. a course). There are different tools to represent and organize these knowledge items and, in this case, conceptual maps have been selected as one of the more flexible and powerful techniques to support this process. Concept maps are graphical tools for organizing and representing knowledge. They include concepts, usually enclosed in circles or boxes, and relationships between concepts, indicated by a connecting line linking two concepts.

Starting from the conceptual maps representing the instructional domain and the technological one, the processing performed by TAGGE is organized in two steps. First, the learning requirements are fed as inputs to the TAGGE environment. These variables are used to modulate instructional issues such as learning objectives (e.g. getting theoretical knowledge or promoting hands-on skills), course resources (e.g. lecture handouts or lesson scripts), learning tasks (e.g. assignment, project elaboration or portfolio development), or assessment activities (e.g. summative vs. formative strategies). Once the basic instructional concepts have been selected, their relationships with other descendant concepts are searched. The second step starts when concepts located at the technological map are "detected" using relationships coming from instructional "leaf" concepts. These technological-based concepts should be instances of higher class concepts in the map (e.g. Desktop Sharing in a Tablet PC context) which define the category concepts used to generate the teaching guideline. Attached to each selected technological category, several guidelines can be configured as output of the TAGGE system. These guidelines will then be used by instructors to adapt traditional courses to a new technology-supported educational approach.

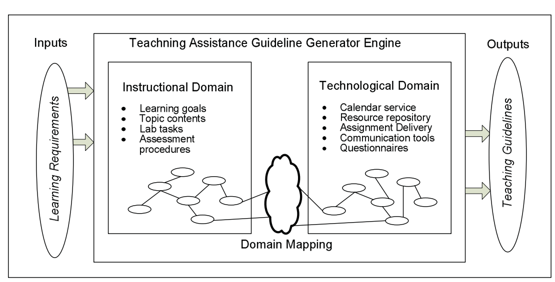

Figure 1. TAGGE. Overview.

Next, we present two conceptual maps which are core elements in our approach. The first one is associated to the instructional domain in a specific educational context, and the second one is related to the Tablet PC domain.

IV. CONCEPTUALIZING THE CONTEXT

In order to illustrate the proposed approach, this section describes a specific context where TAGGE will be applied. On the one hand, Computer Technology, a first-year compulsory course in Computer Engineering has been chosen to describe the instructional domain. On the other hand, Tablet PC devices have been selected as the technological elements in this context. Once both domains have been defined, conceptual maps should be built up in order to organize the corresponding knowledge items.

Fig. 2 shows a conceptual map aiming at describing the instructional model of the course entitled Computer Technology, object of our case study, before integrating the new technologies. Elements located at the top of the map introduce, on the one hand, how sessions are organized and, on the other hand, the assessment strategies. In particular, instruction is organized in face to face lectures, problem-solving classes and laboratory sessions. Instructors take the main role in lectures, whereas both problem-solving and laboratory sessions are focused on the student activity. The lower levels of the map describe the general goals of the different sessions as well as the specific resources that they use. Additionally, this part of the map provides information about what kind of skills students should improve in the different sessions, such as cognitive skills in lectures, communication skills in problem-solving classes or hands-on skills in laboratory sessions. In relation to assessment strategies the map enumerates different approaches that are taken (multiple-choice tests, problems, hands-on activities, student in-class activity). Moreover, it shows some relations with the methodological aspects and how the results may be used.

Fig. 3 depicts a conceptual map that tries to organize the knowledge about Tablet PC technology in a comprehensive manner. In order to better understand the different aspects it covers, we will try to distinguish different areas.

On the top left side of the map, the physical aspects of Tablet PCs are addressed and their main features, such as portability or mobility, are presented. This area also introduces the elements that characterize these devices as a special display screen including a digitizer, and a digital pen, which gives name to a broader family of devices, the pen-based technologies. The three types of Tablet PCs currently available on the market are showed as well: a) slate, b) convertible, and c) hybrid.

On the top right side of the map, different services provided by this technology are displayed, such as presentation delivering, interactive whiteboard, polling, desktop sharing and videoconference. Connected to these services those aspects that may be promoted, are presented as: note taking, collaboration, feedback or communication. This area deals also with specific operating system or software applications related to these devices.

Finally, the map also introduces at the bottom side area the capabilities of digital ink as a key concept in Tablet PCs. In particular, the possibility of using handwritten inputs allows users not only to write in a more natural and free way, but also to mark, to sketch or to draw, among others. In this section, the ability to use a pen to directly write on the surface of a computer screen is also related to the activities that may be fostered, such as: brain storming, prototyping, designing, reviewing, annotating, etc.

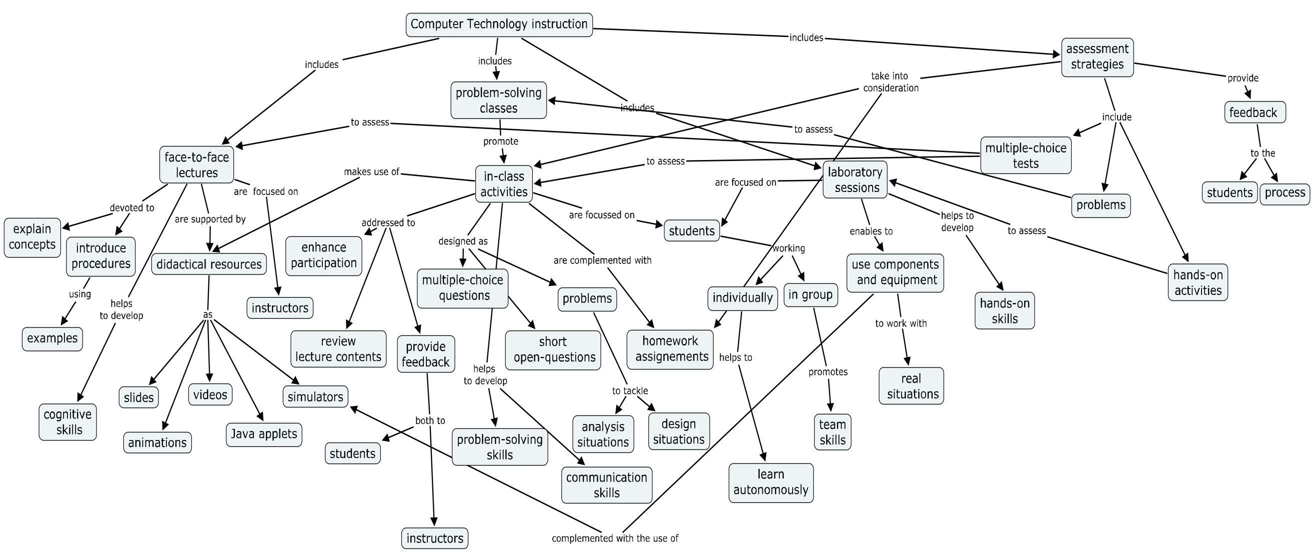

Figure 2. Conceptual map of the instructional domain: Computer Technology course.

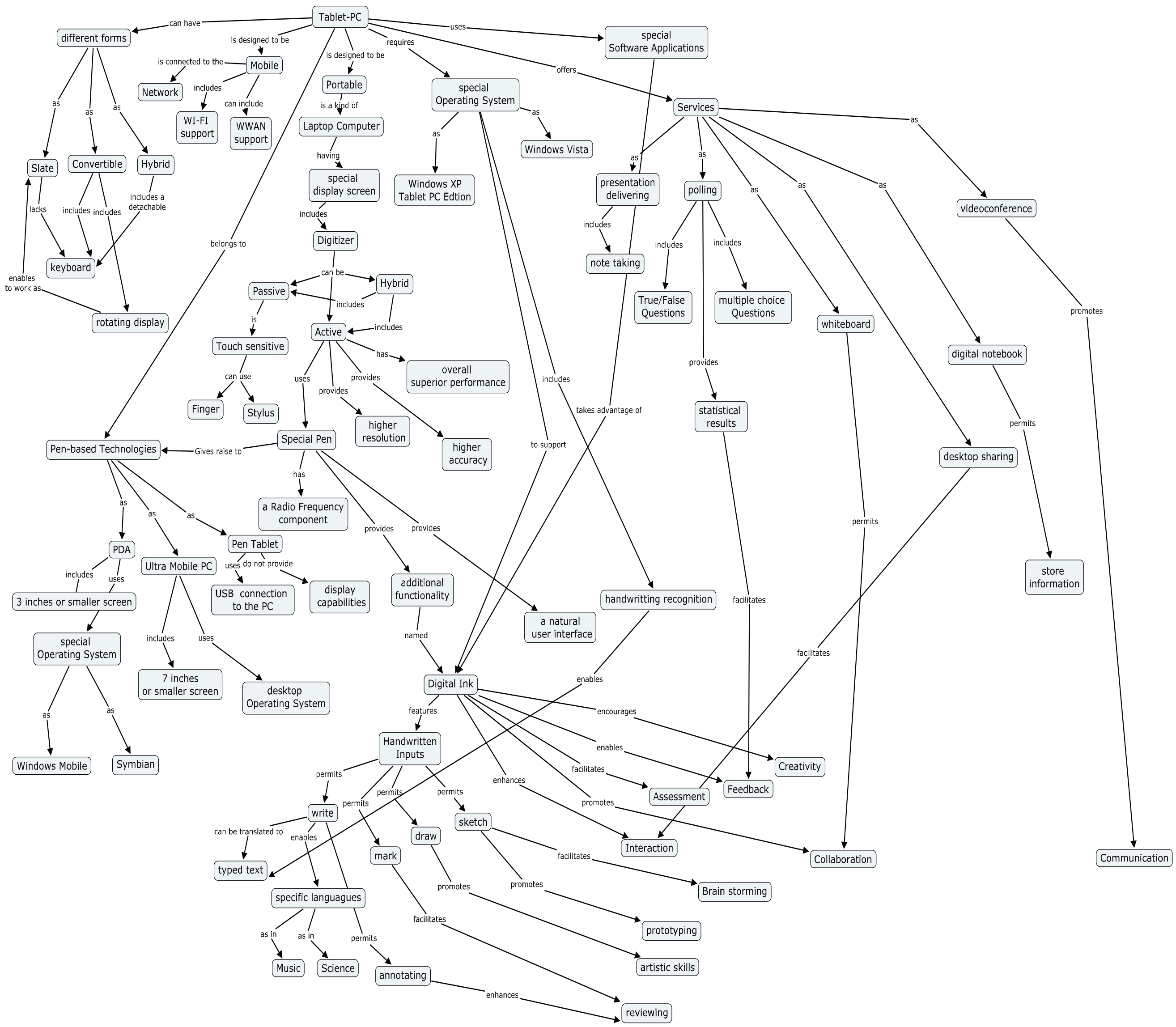

Figure 3. Conceptual map of the technological domain: Tablet PC

V. OBTAINING THE TEACHING GUIDELINES

This section describes the application of the proposed teaching approach to the context example presented in the previous section As stated in the TAGGE description, learning requirements represent the inputs that help to describe the specific context. Concerning the Computer Technology course, over the last five academic years have been observed the following problems: a) pupils' lack of motivation; b) low class attendance rates; c) high course dropout rates; d) low participation and student interaction, and eventually, e) poor students' performance. These issues are also common in other first-year courses. Furthermore, the discipline demands abstract reasoning to understand how semiconductor devices and logic circuits work, problem-solving skills to tackle analysis and design situations, usage of computer simulation tools to help modeling those devices and circuits and additionally, a good knowledge in Physics (more in particular, in topics related to circuit theory).

Once the learning requirements have been set up, the first step of our approach consists in feeding them to our instructional domain in order to decide which are the basic instructional concepts we should focus on. In our particular case, we determine that initially, we should face those instructional factors related to the learner profile, such as engagement, interaction, participation, or feedback; then, we should address the issues related to the discipline itself, trying to obtain a more realistic and motivating approach, by using multimedia resources, computer tools, additional examples, etc. When we try to match these basic concepts to our instructional conceptual map, we find that: a) in-class activities should be emphasized as a way to create more interactive and cooperative sessions; b) those didactical resources that promote student participation should be strengthened, as they could improve both face-to-face lectures and promote autonomous learning; c) assessment strategies should be shaped in order to track learning attainment in a continuous way and also to provide feedback to students and to the process.

The second step of our learning approach connects those basic concepts coming from the instructional domain to the corresponding ones in the particular technological domain. In relation to the Tablet PC domain, it leads us to exploit the inking functionalities and to select which services fit better our instructional issues. In our particular case, we observe that: a) delivering services can contribute to foster student participation and cooperative learning; b) desktop sharing services can help to take the best use of multimedia resources or computer tools and, at the same time, also facilitate the student active role; c) polling services can assist both students and teachers to obtain timely feedback about student attainment and what is better, to facilitate mechanisms to adapt the teaching strategies to the learner's needs.

Finally, teaching guidelines represent the outputs of the process and describe how the technological domain could contribute to fulfill the addressed learning requirements. Table I summarizes the outputs in our case.

TABLE I. TEACHING GUIDELINES

Tablet PC issues	Instructional issues	Learning issues
Presentation delivering services, included in tools as *Classroom Presenter* or *Dyknow*, make use of digital ink functionalities, could be used to:	Increase the instructor's flexibility while lecturing. Facilitate student note-taking. Enable submission of student in-class activity to the instructor and further discussion. Permit archiving of both instructor presentation and student submissions.	Student participation Cooperative learning Enhanced communication with other classmates and instructors Timely feedback to students and instructor.
Desktop Sharing service, as provided by *Yugma*, could be used to:	Engage students in computer simulations introduced as in-class activities. Enable students to assume the presenter role in face-to-face lectures.	Realistic approach of the subject Simulation tools, as PSpice Student engagement
Polling services, also included in tools as *Classroom Presenter* or *Dyknow*, could be used to:	Promote student attainment. Gain knowledge about students understanding related to key course concepts given in lectures. Review misunderstandings and propose reinforcements.	Student self-esteem and confidence Timely feedback to student and instructor
Digital notebook services, as offered by *Microsoft Office OneNote*, could be used to:	Collect all the activities done through the academic year. Review student tasks and provide students with comments and learning recommendations.	Student engagement Student activity tracking Continuous assessment

VI. CASE STUDY & RESULTS

This section reports how the former approach was applied during the spring 2009 semester to Computer Technology (5554), a core course in our Computer Engineering Bachelor, at the Universidad Politécnica de Valencia. The course has 7.5 credits (75 teaching hours), distributed in lectures, problem-solving classes and laboratory sessions. 10 faculty members are involved in the course that the last academic year had an enrolment of 300. Students used to be distributed in 5 lecture groups, 10 problem-solving groups and 15 lab groups.

At present, the course includes two hours of lecture and two hours of problem-solving session per week. In both cases, instructors have a prevalent role whether exposing the contents, supported by a slide presentation, or solving the problems on the blackboard. Several attempts have been made to increase in-class student participation during the last academic years. However, many students are reluctant to present their solutions on the blackboard and what is worst, some declared to drop the course due to the participation demands. As a consequence, these attempts have not significantly improved the overall scores.

In order to apply the approach in this new technology setting, an additional group of just 20 students has been defined. Although this figure could seem very low, it often represents the actual number of students regularly attending to problem-solving sessions.

To measure the effectiveness of the approach, two sections have been compared, the experimental group (20 students) using the Tablet PCs following a 1-to-1 computing approach, and a control group (34 students), following the traditional teaching methods. During all the term we have mainly used *Classroom Presenter*, a Tablet PC-based classroom interaction system that supports the sharing of digital ink on slides between instructors and students to increase the instructor's flexibility while lecturing.

We have used final scores as the main performance indicator, since they were a direct summation of the evaluation of the different activities included in the semester. A 30% passed the course in June in the treatment group while only an 18% in the control group. Other remarkable evidence is that the percentage of students taking the final exam in the experimental group was a 70% while in the control group was only a 29%. Class attendance has also considerably increased: a 60% attended at least 67% of the classes in the experimental group while only a 32% in the control group. Moreover, drop-out rates in the experimental group decreased below 25% while reached almost a 60% in the control group.

VII. CONCLUSIONS

In this work we present a teaching approach that enables the generation of guidelines for technology-supported courses. The proposed approach is based on the conceptualization of instructional and technological issues using concept maps to represent the knowledge provided by educational technologies such as Tablet PC and digital ink. The proposed approach provides teaching guidelines addressed to design and develop both lecture materials and active learning experiences, in a systematic and flexible way. The obtained guidelines have been tested in a case study conducted in Computer Technology, a first-year Computer Engineering course. The results of the test during the spring 2009 semester have revealed a higher degree of students' engagement and an increment in class attendance. We also consider developing computer tools which enable the automatic processing of conceptual maps in order to facilitate the generation of teaching guidelines.

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M-learning tools on distance education

Overview and Case Study

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Abstract—**This paper shows a pioneering project in education with the use of cell phones and other mobile devices. The mobile learning environment was developed by Fazion Sistemas and currently is at the Universidade Fernando Pessoa (Portugal). The paper presents an overview of mobile-learning concepts, its barriers, challenges and trends.**

Keywords- m-learning; distance education; mobile application, mobile learning; e-learning; enginneering education.

I. Introduction

Today people are used with mobile phones, and pay to communicate with people whom they like or with whom they work, either through direct conversation or by exchanging messages. In fact, the text messages play a very limited role in communication, either by poor information quality or high costs. While the "idea" of the personal computer largely derived from the look of a typewriter and calculator, usually born in the company, the phone came from the merger of the notebook and telephone, being something very personal.

We must learn from this change - home versus business – and what should be done to enhance phone quality when developing applications. Today, more than ever, businesses are stepping forward to bring people together because people like to relate to each other, regardless of business they do. If a mobile network project can be developed in this format, aimed at relationships, then this is the path. [1]

Currently there are three areas where mobility can bring immediate fruits and strategic importance for organizations, which are "mobile-business", "mobile-commerce" and "mobile-learning", or simply "m-learning".

M-learning can be considered an offshoot of e-learning. But, in fact, considering that e-learning enabled the distance learning using the Internet, m-learning goes beyond by allowing the user access to perform anywhere, even on the move, and the device becomes in fact a mobile repository of information. The concept of education with the use of mobile phones covers a wide range of opportunities:

- learn anywhere and in motion, simply carrying a personal mobile device;
- learn by interacting with different people through social networks, forums, etc.;
- archive and order a wide range of information, using memory resources of the device;
- create, with equipment features, image files, video or text, attaching them to the systems of communication and learning;
- consult various information such as grade, messages, calendars, among others.

This paper does an overview about m-learning and shows a pioneering project in education with the use of cell phones and other mobile devices. The project is at Universidade Fernando Pessoa (Portugal) and the basic system refers to academic information such as calendar, information about the subject, grade and environment forum between students and teachers. Universidade Fernando Pessoa uses a very successful e-learning environment based on the *sakai* collaborative platform [2] and sees it as a natural expansion of e-learning environment towards m-learning.

The m-learning project presents several challenges and barriers to transpose, either on technical or cognitive issues. As an example, there is no standardization on the several mobile platforms or devices, screens vary from device to device and the industry is not worried about data traffic or computation basis when compared to voice traffic and its respective earnings. The cognitive aspects of mobile learning is yet more obscure, as the research on this area is just in its very beginning and depends on new experiments and trials.

The project with Universidade Fernando Pessoa is a real case use and is also object of study and research. The paper begins with an overview of mobile learning concepts and describes the context of the project at Universidade Fernando Pessoa.

II. Evolution of Distance Education - a Brief History

The evolution of distance education can be divided roughly in three different stages: 1) the distance learning, 2) the electronic learning, and 3) the mobile learning phase.

The distance learning stage, abbreviated as d-Learning, begins with the industrial revolution around centuries 18^{th} and 19^{th}. The industrial revolution brings several new possibilities for communication, and one of the most important is the printing facility of large volumes of books, newspapers and other documents. The post service evolved those days, and the expansion of railways, with trains arriving or passing through distant places, got the advantage to take people together or more connected then ever before. The first distance education courses were based on books and correspondence, and people away from large centers could receive materials, study alone and conduct tests and relationships through correspondence. In the United Kingdom the University of London opens its education program in 1840. The concept of distance education evolved until the last century when, during the 1970 decade, the first "Open Universities" opened in Europe (UK, Spain and Germany).

The electronic learning, or e-Learning, comes with the electronic revolution and the internet. The arrival of electronic communications has enabled a new level of access and communication for education, first with the radio live broadcasts of courses, and after the television era came. Then in the nineties arrived the internet network that allows a wide range of new possibilities for communication, especially interactive, which was not possible with radio and television. Learning systems using the internet can provide content, promote discussion forums and chat in real time, show videos and create other possibilities as an entirely new way to educate through the use of web tools. The intensive use of internet was possible due to several facts:

- deregulation of communications, followed by telecom privatization around the world;
- development of personal computers and its popularization in the '80s; computers became easier to use and price came down year by year;
- communication networks have switched from analog to digital; this digitalization allowed the development of new transmission technologies and protocols and conditions to compact more information in a single "packet";
- Internet has become public in the '90s; earlier used by academic or military reasons, then became public and spread out.

After the internet revolution came the wireless revolution that brought the new stage of mobile learning, or m-learning. A personal communications revolution began at the turn of the century when the number of mobile phones surpassed the number of landlines of the traditional telephony. There were 500 million handsets in 1999/2000, and in 2008 there were more than 3 billion mobile lines in the world. Features were added every year, such as photography, music and video in all devices. In these handsets the computing power is already higher than the desktop from a few years ago, with increased memory and sophisticated web browser. Currently there are three times more mobile phones than PCs with Internet access, and we are in an era of global mobility, where 50% of workers spend up to half their time outside the office. The cell phones are personal items, and define a personal style. But the experiences with the use of mobile devices for education are just beginning, and most of them focuses on implementing, literally, the versions of the web to the phone while using the browser, or merely implementing very simple learning objects or small games [3] [4]. An overview about m-learning can be found in [5].

III. Concepts of M-Learning

As a first view, the m-learning can be considered as an offshoot of e-learning, allowing a wide range of opportunities in education. Just like e-learning that has become an entirely new way to teach and transfer knowledge, m-learning is now showing a horizon of new challenges and possibilities. Some of these challenges and possibilities can be described as:

- learn anywhere, everywhere, and in motion - just simply carry a personal mobile device wherever you go;
- learn by interacting with different people, whether in the social community or through social networks, forums, etc;
- archive and sort a wide range of information, using memory resources of the device (the information will be always at hand);
- create, using the equipment features, image, video or text files, and then attach to the systems of communication and learning; this way all participants of the learning network can be knowledge collaborators;
- continuous extended library - information such as grade, messages, calendars, among others, can be always updated and seen.

Devices for this kind of learning are in continuous evolution and going for a technological convergence. Today one can see equipments for training and education varying from common mobile phone to new advances like smartphones, palmtops, pocketPC and several kinds of personal digital assistants.

IV. Challenges of Mobile Education

The main overall challenge is to develop new paradigms to support education on mobile platforms. Paradigms which are different from the ones that emerged from the previous internet era. New wireless paradigms such as:

- collaborative learning – people are now connected all the time and can collaborate in real time, asking, answering, discussing and participating in a very democratic way;
- corporate education – as the workers are more and more on the go and out of office, the corporate education must pass through mobiles;
- collective generation of knowledge – as the device has powerful tools (camera, recorder, text, etc) and is always connected, it should be used to generate knowledge from the field;
- the growing experience of young people with social networks can be turned on an advantage for the mobile-learning.

Another complex challenge is the mobile content authoring. How to develop a new authoring platform for content development, how to solve the markup text for different devices and formats, and how to use the small interface to show text and images are fundamental questions [6].

Existing content in e-learning must be adapted for the new devices, and this should be done by automatic processes. This can generate new business models, like new platforms for m-LMS (learning management systems), and new businesses to interact with existing ones.

The challenge of the mobile features: every year (or month!) new features are built on the mobile devices and this is very exciting. How to fully exploit these new features, such as geo-location, motion sensors, photo and video, to make the educational experience as interactive as possible – that's the defiance to deal with.

V. Barriers to M-learning

Despite the evidence of the wireless revolution and all the possibilities it brings for several areas, there are yet important barriers for de m-learning adoption. Some of these barriers can be described as follows:

- the cost of packet transmission (WAP, GPRS, 3G and other) is yet impeditive in several countries, mainly in poor regions and even in developed countries, maybe due to the business models of telecom operators which are yet focused on voice billing and short message services;
- the size of devices is a problem because the screen is considered small, the keyboard is not practical to text, and there is no uniformity of devices in the industry; some of these problems were surpassed by the touch screen interfaces, but dimension is an usability question to solve [6];
- multiple platforms, multiple operators – each manufacturer constantly launches always new devices with different dimensions and features, and telecom operators have not a standard of data quality transmission or business models, what puts difficulties for developers in general;
- there are only just few experiences in mobile-learning, which are yet incipient and often discontinued [1];
- reactivity and the conservatism of educators – most of them see these kind of technologies as a new problem to deal with, and sometimes prefer old ways which they are used with;
- new technology adoption is a barrier because depends on early adopters;
- the need to produce new content and learning objects could be a strong barrier because teachers and researchers do not have this know how [7];
- despite the huge mobile phone installed base, development of applications for mobiles is still something very embryonic [8];
- owing to the students misuse of mobile phone at schools (for instance counterproductive conversation at classes, ringtones and so on), there is yet a negative image of mobile within the educational environment.

VI. M-Learning Platform Typical Tools

When we think of mobile-learning tools we can classify them into two major groups: 1) access to academic information (schedules, marks, information about educators on the educational institution, etc.) and 2) access to educational content. The second group should consider the use of assessment tools of learning, like the creation of multiple choice questionnaires, and how to associate this kind of testing with confidentiality and safety measures, as well as the correct user ID system at the completion of the assessment.

Considering these two groups we can enumerate the following functions that are typical of mobile platforms:

- alerts and alarms: set indicated to alert on events on determined schedules or agendas;
- direct communication tools: peer to peer possibility of communication between educators and students;
- multiple choice systems: development of evaluation questionnaires;
- educational games: how to make content more attractive to the audience, development of learning objects considering the game designing style;
- records, schedules, evaluation scores: basic tools for access to scholarly information;
- searching tools: words, glossary, dictionary, tools supporting the dissemination of content;
- links to mobisites: how to make content more dynamic and how to find more references;
- instructional videos and audios: use of multimedia resources to enrich the contents and overcome the monotony of long texts;
- tools to capture information: capture in the field and then send to referral groups, encouraging the use of mobile platforms in times of extreme mobility;
- forums and social networks: the approach is fundamental because participation in forums and social networks in the m-learning universe is a way to boost the mobile employment for education. This trend is in line with recent research showing that mobile phone users have the largest networks of contacts [9].

VII. Major Issues for the M-Learning Future

The future of m-learning, its success and time to adoption depends on a series of questions, like portability, capability of interaction with existing educational methodologies and technologies, the device dimension and related features, data transmission quality, social interactivity and user centered applications. Let's exploit these points further.

The portability of applications: mobile-learning systems must search for applications that can be used in a wide variety of devices, in order to democratize access to mobile-learning and be as less as possible dependent on new hardware launchings.

Hybrid educational opportunities: use of mobile-learning systems operates as a complement to formal face-to-face and e-learning education and could be used as an additional teaching method outside of the classroom, as an online bridge between students and educators, allowing quick exchange of information between these actors.

Small size of devices (screen and keyboard): the easiness that younger generations adapt to mobile devices can predict that actual difficulties will be overcome in the same proportion as the devices become more sophisticated and prices go down. Just observing the ease with which young people create text messages on their cell phones and we can glimpse that the small keyboard will not be an obstacle in a short time.

Quality of transmission networks: the enhancement of the quality of transmission network in many countries, the quality of its coverage and even the possibility of ever-increasing use of free Wi-Fi will bring more and more ease of access to information.

Interactivity: one of the biggest attractions of mobile networks is the possibility of being connected to the network all the time and interacting with other people through it. The design of platforms that make use of principles of social networks to disseminate knowledge and not just entertainment is the path to education in the near future.

User centered applications: tools for mobile-learning should be created in the user viewpoint, i.e. the student. The conservatism of educators must be overcome with other strategies, through training and development of tools for "back office" that encourage the use of mobile-learning. The fact is that the applications to be installed on mobile phones should be visually attractive, user-friendly and stimulating for students, and certainly soon a specialty area of design will be established, geared specifically to create visually exciting interfaces for mobile phone screens.

VIII. Case Study: UFP M-Learning Project - Universidade Fernando Pessoa

The project developed in partnership with the Universidade Fernando Pessoa aims to provide students, faculty and staff an innovative way of access to information, as well as a versatile tool for exchanging messages and a real time mode to the promotion of discussions on relevant topics and disciplines.

The mobile-learning application is designed to live alongside with other ways of access to information already available at the Universidade Fernando Pessoa. Among the technology platforms of education available in the institution we can cite the environment of e-learning developed with the *sakai* [2] collaborative learning tool, and the access to virtual office via the Web.

The e-learning environment provides access to documents relating to each discipline. In principle, each student has access to courses that are enrolled in a given period. Within each virtual class is offered the content, the teacher information, the possibility of a conversation environment among students and teacher, which can send messages to students about facts that occur during the school year. Also available is a forum environment, where students can discuss topics of interest related to the discipline on focus.

In the virtual secretary office environment, which is also accessed via Web browser, it is possible for the student to access academic information such as calendar, evaluation scores, financial situation as well as information about the services available in the university.

The mobile-learning application developed by Fazion to University Fernando Pessoa took account of these environments and attempts to build a single application to gather information more meaningful to the daily lives of students, faculty and staff. They can have in their hands palm, even when moving, the information deemed essential to their routine. For this step of the mobile-learning application development Fazion conducted a survey of the most relevant needs and how they should arise in the interface of mobile phones.

The goal of this mobile-learning tool is to allow access and storage of essential information to the user. In the case of the student, the real sense that is possible through the application be directly related to the school year in which he/she is. When updating the information on the agenda, the app shows the information of the subjects the students are to attend at the current school year. Such information, after updated on the device, will remain stored there. When the student does an update on another school year, the previous period subjects will be replaced by new subjects, leaving only the history of the marks obtained before. A major advantage of this application is just the fact of allowing the student to have in one place all information related to his/her grades. The information is available personally in the particular device, without having to login every time one wants to see it.

Another important feature is the ability to send alerts from teacher to students. By accessing the Web Portal tool related to the m-learning app, the teacher sees the list of their students sorted by discipline. This feature is useful for sending last minute alerts, when students are already on the move, for example if a change of venue or time made just before the start of a lesson. In this case sending an e-mail can not work and SMS can be tricky, considering the list of students. With this tool the teacher can ensure the communication with the students in situations of extreme mobility and with just one click.

Also included is the possibility for the student to consult information from the faculty during the school year, and then have in the palm of the hand the information needed to contact them at any time (their agenda at university, phone and e-mail). Information about the core services of the University, like library and department hours as well as phone and email contacts are also included.

To create a social networking environment among student's users of the tool, m-learning app has inserted a forum, which allows the creation of discussions about the subjects taken at the school year, with the teacher's intermediation. The goal of this tool is to encourage the exchange of information among students, especially when they are out of the classroom, providing the questions anywhere and even encouraging reflection on specific topics. This is very interesting to occupy lost times, such as when one is commuting public transport. This forum is also an environment for content exchanging between students (text, music, videos and other docs).

Finally there is a user profile area. The first login to the m-learning app shows the form to fill together with the login and password to access the system. After this initial insertion there is no need to re-fill the login, which ensures quick access to information. This is a slight and important difference to the traditional virtual environment office, where you must reenter your login and password every time access is done.

IX. TECHNICAL ASPECTS OF THE UFP M-LEARNING APP

Java programming language was used to develop the tool with its ME (Micro Edition) architecture, which consists of a collection of specifications and technology created by Sun Microsystems and the JCP (Java Community Process) to develop applications that will run in environments with limited resources, like small devices with low-capacity memory, small display and limited power capacity. The main factor that influenced the choice of language was driven by portability across platforms, enabling the tool to be used for a wider range of users, no matter the mobile device manufacturer or service operator.

As shown in Fig. 1 the architecture of the application is divided into three concepts.

- Service Platform – Platform responsible for communicating and processing of content that could to be provided in a format that a low power processing device could receive and manipulate information easily. The concept of "Web Service" was used for implementation of the platform service provider. The concept of service adds to the m-learning platform flexibility for contents to interact with systems developed on different platforms, exchanging information in XML (eXtensible Markup Language). This characteristic makes it an interoperable platform.

- Web Platform: Tool responsible for managing the content and audit system access. The web tool communicates with the institution software legacy to provide writing and reading content availability on the institution portal. This flexibility provides real-time evaluation scores, class schedule as well as other content and interactions with students.

- Mobile Platform: it is able to communicate with the service platform and do the exchange of information and do the presentation of content and learning objects. As already mentioned, the mobile architecture is based on Java ME, making it independent of operational systems (OS). Through the mobile platform, the user can monitor contents, score and schedule and has the opportunity to ask questions to the teachers and receive public or private notices. The major difference of this approach is that students have access to information, consulting or even interacting using mobile handset, regardless of physical location. Another important factor is that with this approach, the channel or medium of communication between the mobile platform and service platform becomes flexible. User can use any available technology, being able to access the service platform via GPRS, EDGE, Wi-Fi, 3G or other technologies available.

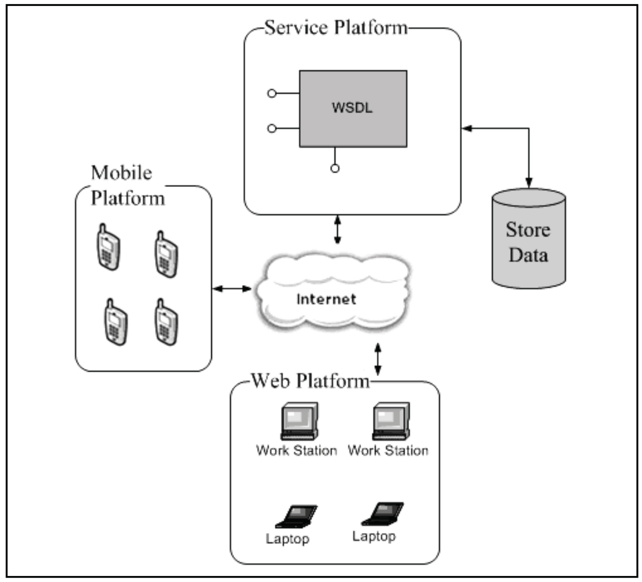

Figure 1. M-learning application architecture.

A. Tools and diagram

The main diagram of the mobile application framework is shown in Fig. 2. It is only illustrative and presents a diagram of the interfaces and flow of screens used in the mobile tool implementation. With this kind of diagram is possible to preview interactions between the User and the device, allowing efforts to design more user-friendly applications.

B. Mobile tool app

The "Beta" mobile version of the UFP m-learning platform allows the students to access information like evaluation scores and agenda of the disciplines to which they belong, as well as relevant information from their teachers and services provided by the university.

Using the mobile handset it is also possible to participate in forums linked to the disciplines, and receive warnings from teachers and sectors of the institution. Fig. 3.a illustrates the main screen of the mobile tool.

Fig. 3.b illustrates the layout used to provide evaluation scores. For future reference the student can obtain the current grade of a particular discipline and store it in the phone.

Through the module "message" the student can receive in the cell phone not only reports but images and texts in various formats (as exemplified in Fig. 3.c).

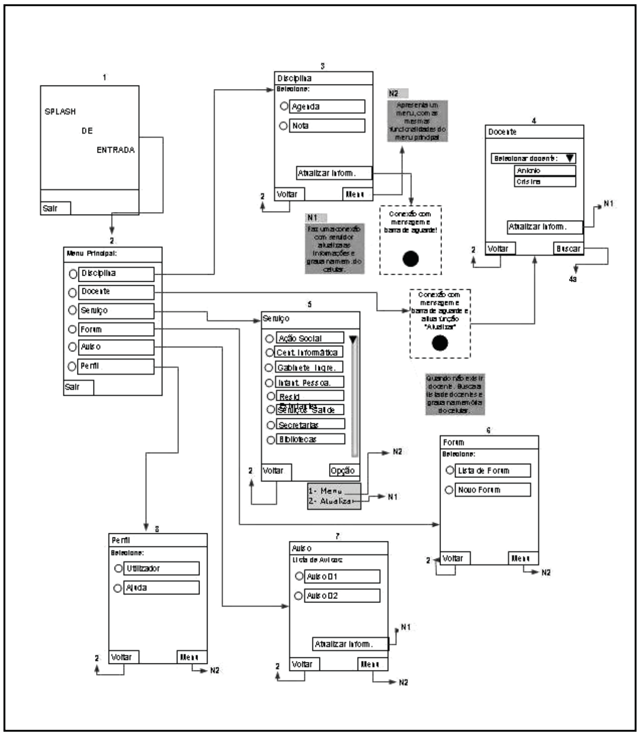

Figure 2. Interface flowchart.

Figure 3. Mobile learning interfaces.

A major differential of the mobile tool is the flexibility given to the user, which permits him to have access to content anywhere and be able to interact with teachers, within the university campus or in any other location. Fig. 3.d illustrates the forum entrance functionality.

C. Web tool app

The mobile learning system application has a web portal that operates as an original authoring tool, responsible for monitoring the content of education as well as handling and sending grades and reminders to students. Through this portal the teacher can interact by sending content or answering questions through the forum features, and sending alerts. Fig.4 illustrates some of the interfaces of the web portal.

At the "forum" module the teacher may add questions or even answer questions from students remotely via the mobile platform. In this module the teacher can create new discussions withim disciplines, encouraging and urging the students to search for knowledge.

At "alert" module the teacher can monitor and send public messages to all students enrolled in his/her courses, or can also send private messages directed to a single student. Through this module teachers can provide content of their disciplines and also notify students of the existence of new content.

The web tool also enables to audit the use of the system, recording date and time of use of both the web tool and the mobile tool. Fig. 4.d illustrates an example of the logs of requests occurring in a given period. Note that through this module it is possible to identify the resources more accessed by a particular class of users, building a customized social network to analyze. The possibilities of monitoring and auditing the connections, and the interaction between the mobile application and the web service are fundamental functions of the system.

X. CONCLUSIONS

Seek for new ways and tools in education is a challenge increasingly compelling. University Fernando Pessoa, from the city of Porto in Portugal, has chosen to look for new technologies to make the art of teaching more interesting and motivating. Since its beginning the organization has chosen to develop tools and methodologies of teaching aligned with the state-of-art of technology. This was the thinking that led to the partnership for the development of the m-learning tool, which represents a differential respect to other higher education institutions globally. Thinking about the student and giving him different forms of interaction with the University is the way to make learning more interesting.

In this sense, the whole process of developing this m-learning tool used as fully as possible the information already available in the university database for conventional forms of web access, and created new options for communication between students and teachers through messages and forums.

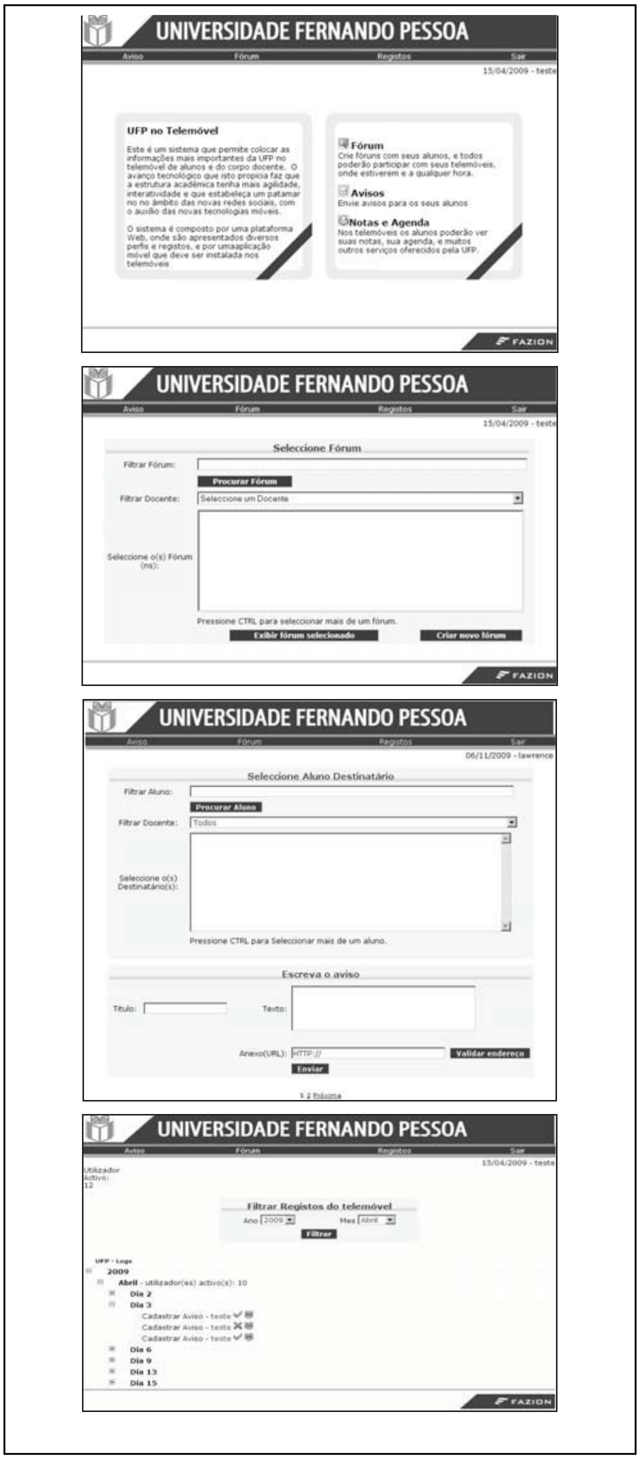

Figure 4. Web portal learning interfaces.

The continuous use of the m-learning tool in the university and the feedback from users will allow new questions and new enhancements, important for the maturation process of mobile-learning as a whole. For instance, engineering courses that require laboratories and other face-to-face classes may be, in parallel, facilitated by new learning objects and relationships that may be available on mobile phones. This new way of educating opens potential applications, especially in the area of interpersonal relationships in online interaction, and provides the experience of knowledge even when outside the traditional educational environment.

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Teaching Digital and Analog Modulation to Undergradute Information Technology Students Using Matlab and Simulink

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***Abstract*—Teaching mathematical intensive engineering based courses to undergraduate Information Technology students poses a great challenge to instructors. In this paper we provide an efficient and effective method for teaching digital and analog modulation to undergraduate students enrolled in an Information Technology program which does not require a strong foundation in mathematics as in the case of an Engineering program. The used approach utilizes Matlab packages, Simulink, and Communication Blockset to simulate analog and digital modulation techniques avoiding the derivation of any mathematics formulations and without coding. A survey that was distributed to Information Technology students who were taught using this approach showed a high level of satisfaction in understanding all modulation concepts.**

Keywords: Matlab; Modulation; Simulink, Communications Blokset

I. INTRODUCTION

Matlab is a numerical computing environment and a 4th generation programming language. It is a high level language and interactive environment that enables users to perform intensive calculations based tasks very fast. Developed by Mathworks [5], Matlab allows matrix manipulation, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs in other languages. Matlab has been widely adopted for over 25 years in the academic community, industry and research centers. It was originally written to provide easy access to LINPACK and EISPACK software packages [1-4]. The Matlab software provides the users with a large collection of toolboxes and modules for a variety of applications in many fields of interest.

Simulink [6] is an interactive graphical tool that was added to Matlab to make the modeling and simulation of various systems as easy as connecting predefined and designed building blocks. Simulink contains many block sets that are used in almost all applications such as the communication block set and the signal processing block set.

Research using Matlab/Simulink has been conducted for many years in academia, industry and also military. Many researchers have published papers using Matlab/Simuling for simulating particular systems. For examples, the authors in [7, 8, 10, 11] used Matlab/Simulink to model components and performance of various wireless communication systems. Others have utilized Matlab/Simulink as a research tool for army and military based applications [13, 14].

Matlab has been used as a teaching aid in many subjects such as mathematics, physics, heat conduction, control systems, mechatronics, mechanical design, circuit design, communication theory, random processes, electronics and many more disciplines and applications [4, 5, 9, 12, 15, 16].

In this paper, we provide an efficient and effective method for teaching digital and analog modulation techniques to undergraduate students enrolled in an Information Technology program which does not require a strong foundation in mathematics as in the case of an Engineering program. The used approach utilizes Matlab and Similink blocksets to simulate analog and digital modulation techniques. To assess the degree to which Matlab/Simulink helped students to understand the taught concepts, a survey was distributed to students and the results were analyzed using Statistical Package for the Social Sciences (SPSS [25]) and presented in this paper.

The rest of the paper is organized as follow: In section 2, analog and digital modulation techniques are introduced. Section 3, discusses the use of Simulink and the communication toolboxes available in Matlab to study modulation techniques. Section 4 shows the results of the students' survey, and section 5 concludes the paper.

II. ANALOG AND DIGITAL MODULATION

In general, modulation is used to give the transmitted signal properties which are best suited to the transmission channel or environment. Specifically, modulation is the process of imparting the source information onto a band pass signal with a carrier frequency, f_c, by the introduction of amplitude or phase perturbations or both. This band pass signal is called the modulated signal and the base band source signal is called the modulating signal [4]. At the receiver end a mean to translate the higher frequencies back to the audio range is implemented and this is called demodulation.

A. Amplitude modulation (AM)

Audio signals at most occupy the frequency range 0-20 KHz (minimum 15 Km wavelength). This range of frequencies is too low to transmit directly as electromagnetic radiation, particularly due to the prohibitive sizes of the transmitter and receiver antennas which would be required. Antennas must have lengths of the order of the wavelength of the EM radiation of interest. Higher frequencies permit much more effective and practical transmission; however, these lie outside the audio range. For example, AM radio broadcasting occurs at frequencies of the order of 1 MHz.

In standard AM, the audio signal is shifted in amplitude by adding a DC component and then multiplied by a sinusoid at the carrier frequency, f_c. The carrier frequency is much higher than the audio frequency band. We consider a mathematical description of amplitude modulation. Following the nomenclature of Couch's textbook [4], let the audio message signal be m(t), where m(t) is band limited to "W" Hz, and let A_c be the message amplitude (or gain).

Let $\omega_c = 2\pi f_c$ be the carrier frequency in radians per second where $f_c >> W$. Then the amplitude modulated signal *s(t)* can be expressed as

$$s(t) = A_c[1 + \mu m(t)]\cos(\omega_c t)$$

$$s(t) = A_c \cos(\omega_c t) + A_c \mu m(t)\cos(\omega_c t)$$

The constant, μ, is selected such that

$$-1 < \mu m(t) < 1$$

The students shall understand very well the above formulas and they have to write codes using Matlab to draw the following curves depicted in Figure 1.

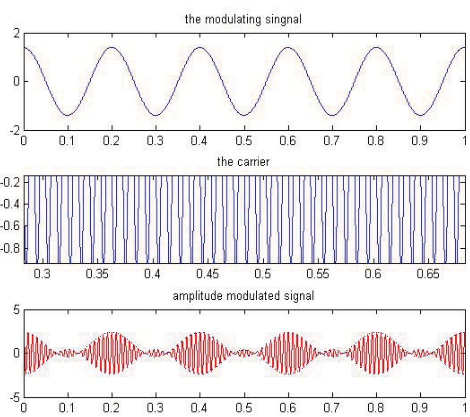

Figure 1: AM modulation using Matlab code

Figure 1 depicts the audio signal, the carrier, and the amplitude modulated signal. This result is a coding the above formulas of AM using Matlab codes which is not easy for the non engineering students.

B. Frequency modulation (FM)

Frequency modulation encodes the message, *m(t),* by making the instantaneous frequency deviation about f_c proportional to *m(t)*. Frequency Modulation is a special case of *Angle Modulated* signaling. In angle modulated signaling the complex envelope is:

$$g(t) = A_c e^{j\theta(t)}$$

Note that this is in *polar form* so we can immediately say what the *amplitude modulation is R*(*t*) and the *phase modulation is simply θ(t).* The amplitude modulation is:

$$R(t) = |g(t)| = A_c$$

The phase modulation is simply *θ(t)* and for angle modulated signals is a linear function of the modulating signal *m(t).* For FM the phase is proportional to the integral of *m(t)*:

$$\theta(t) = D_f \int_{-\infty}^{t} m(\sigma)d\sigma$$

Where the frequency deviation constant D_f has units of radians per volt-second. So the frequency modulated FM signal is:

$$s(t) = A_c \cos\left[2\pi f_c t + D_f \int_{-\infty}^{t} m(\sigma)d\sigma\right]$$

The bandpass signal is represented by:

$$s(t) = A_c \cos\left[2\pi f_c t + D_f \int_{-\infty}^{t} m(\sigma)d\sigma\right]$$

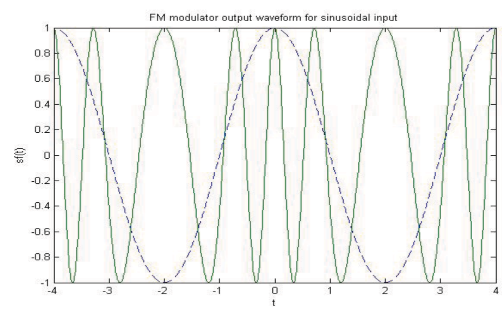

Figure 2: FM modulation

Figure 2 illustrates the Programmed FM modulation using Matlab codes.

III. Analog and Digital Modulation Using SIMULINK and Communication Toolboxes

A. Simulink

Simulink, developed by The MathWorks, is a tool for modeling, simulating and analyzing multi-domain dynamic systems. Its primary interface is a graphical block diagramming tool and a customizable set of block libraries. It offers tight integration with the rest of the MATLAB environment and provides scripting capability. Simulink is widely used in control theory and digital signal processing for multi-domain simulation and design.

Simulink is integrated with MATLAB, providing immediate access to an extensive range of tools for algorithm development, data visualization, data analysis and access, and numerical computation. The Key Features of Simulink include: [6]

- Extensive and expandable libraries of predefined blocks.

- Interactive graphical editor for assembling and managing intuitive block diagrams.
- Ability to manage complex designs by segmenting models into hierarchies of design components.
- Model Explorer to navigate, create, configure, and search all signals, parameters, and properties of models.
- Ability to interface with other simulation programs and incorporate hand-written code, including MATLAB algorithms.
- Option to run fixed- or variable-step simulations of time-varying systems interactively or through batch simulation.
- Functions for interactively defining inputs and viewing outputs to evaluate model behavior.
- Graphical debugger to examine simulation results and diagnose unexpected behavior in designs.
- Full access to MATLAB for analyzing and visualizing data , developing graphical user interfaces, and creating model data and parameters.
- Model analysis and diagnostics tools to ensure model consistency and identify modeling errors.

With Simulink, the user can quickly create, model, and maintain a detailed block diagram of a system using a comprehensive set of predefined blocks. Simulink provides tools for hierarchical modeling, data management, and subsystem customization, making it easy to create concise, accurate representations, regardless the system's complexity. Details on how to create and run simulation models are out of the scope of this paper, for more information on this the reader can look at the following references [6, 17, 18].

B. *Communication Toolbox*

Communications Toolbox extends the MATLAB technical computing environment with functions, plots, and a graphical user interface for exploring, designing, analyzing, and simulating algorithms for the physical layer of communication systems. The toolbox helps create algorithms for commercial and defense wireless or wireline systems, such as mobile handsets and base stations, wired and wireless local area networks, and digital subscriber lines. It can also be used in research and education for communication systems engineering.

The Key Features of Communication toolbox includes [5]:

- Functions for designing the physical layer of communications links, including source coding, channel coding, interleaving, modulation, channel models, and equalization.
- Graphical plots for visualizing communications signals, such as eye diagrams and constellations.
- Graphical user interface for comparing the bit error rate of a system with a wide variety of proven analytical results.
- Galois field data type for building communications algorithms.
- New channel visualization tool to visualize and explore time-varying communications channels.

C. *Simulation of analog modulation*

The students don't have to derive any more the modulation formulas. He/She has just to understand the components of the equation (e.g. AM equations) and start to implement using the Simulink. Figure 3 illustrates the blocks needed to design an AM modulator. The students have to open simulink and drag and drop in the area of work all these blocks. To visualize the modulated and modulating signals, we need to add to the simulator two scopes. Scope 1 shows the original signal before the modulation. Scope 2 shows the modulated signal, it means after the modulation process. The students can also see the modulated signal in frequency domain. They need to drag and drop the Box "BFFT". This Box does the Fast Fourier Transform operation and illustrates the signal in Frequency domain. The students are exempted to know the derivation of FFT formula.

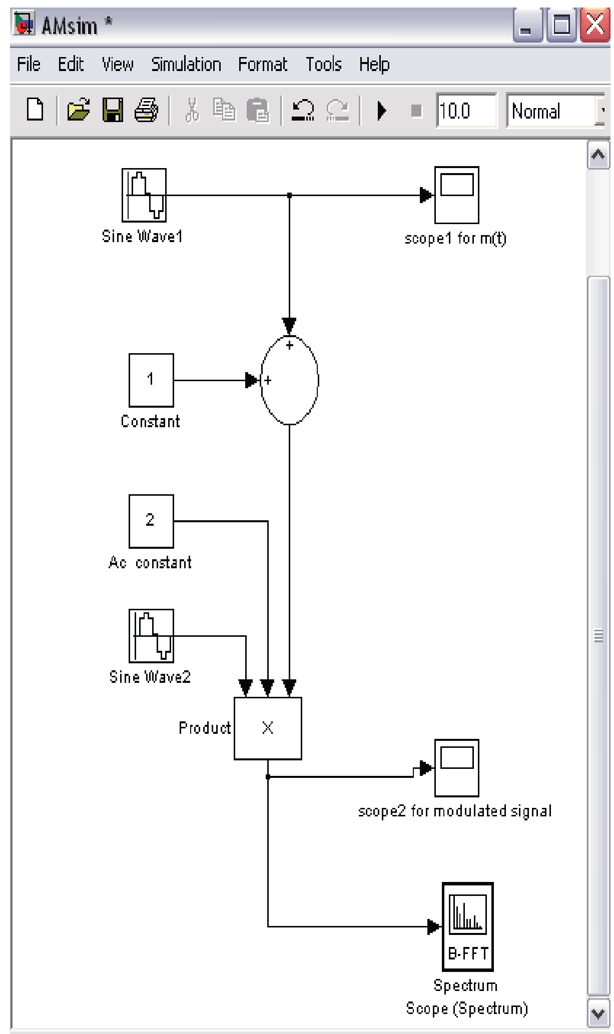

Figure 3: The model of AM modulator using Simulink

Figure 4 shows the audio signal before modulation; it is depicted by the Scope 1.

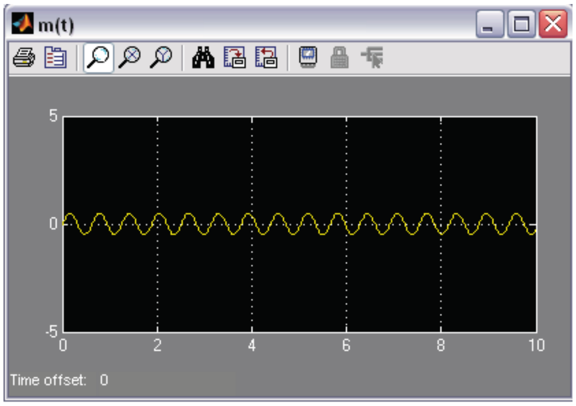

Figure 4: The modulating signal *m(t)*

Figure 5 illustrates the amplitude modulated signal. This signal should be transmitted over the medium.

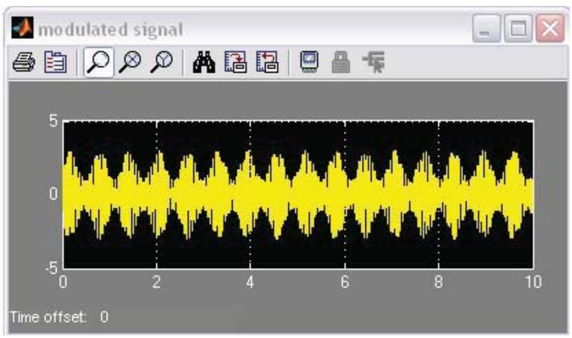

Figure 5: The amplitude modulated signal *s(t)*

The frequency domain spectrum is obtained through a buffered-FFT scope, which comprises of a Fast Fourier Transform of 128 samples which also has a buffering of 64 of them in one frame. Figure 6 depicts the modulated signal in frequency domain.

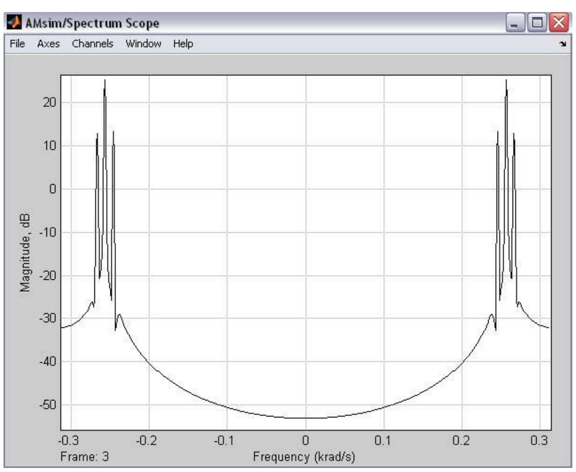

Figure 6: The spectrum of the AM signal *s(t)*

Table 1 below lists and describes the blocks in the Analog Passband sub-library of Modulation by double-clicking on the Analog Passband icon in the main Modulation library, or by typing commanapbnd2 at the MATLAB prompt. For more details, the readers can consult the Mathwork website.

TABLE I. TABLE 1: BLOCKS FOR ANALOG MODULATION

Block Name	Purpose
DSB AM Demodulator Passband	Demodulate DSB-AM-modulated data
DSB AM Modulator Passband	Modulate using double-sideband amplitude modulation
DSBSC AM Demodulator Passband	Demodulate DSBSC-AM-modulated data
DSBSC AM Modulator Passband	Modulate using double-sideband suppressed-carrier amplitude modulation
FM Demodulator Passband	Demodulate FM-modulated data
FM Modulator Passband	Modulate using frequency modulation
PM Demodulator Passband	Demodulate PM-modulated data
PM Modulator Passband	Modulate using phase modulation
SSB AM Demodulator Passband	Demodulate SSB-AM-modulated data
SSB AM Modulator Passband	Modulate using single-sideband amplitude modulation

D. *Simulation of Digital modulation*

Table 2 lists and describes the blocks for digital modulations. Figure 7 illustrates the model for MPSK modulations using Simulink and the Communications block set. The students can vary the parameter “M” and also the Signal to Noise Ratio (SNR) and can easily draw the BER (Bit Error Rate). Figure 8 depicts the results of BER versus the SNR. The student can simulate all type of digital modulations by choosing the adequate Blocks and they can also choose different type of channels. The blocks are respectively Data generator, Modulator, Channel model, demodulator, and the BER calculator. The students are not supposed to know the formula of Probabilities of errors. The model generates a million of bits and can calculate easily the errors.

TABLE II. BLOCKS FOR DIGITAL MODULATION

Block Name	Purpose
M-DPSK Demodulator Passband	Demodulate DPSK-modulated data
M-DPSK Modulator Passband	Modulate using the M-ary differential phase shift keying method
M-PSK Demodulator Passband	Demodulate PSK-modulated data
M-PSK Modulator Passband	Modulate using the M-ary phase shift keying method
OQPSK Demodulator Passband	Demodulate OQPSK-modulated data
OQPSK Modulator Passband	Modulate using the offset quadrature phase shift keying method
M-FSK Demodulator Passband	Modulate using the M-ary frequency shift keying method

M-FSK Modulator Passband	Modulate using the M-ary frequency shift keying method

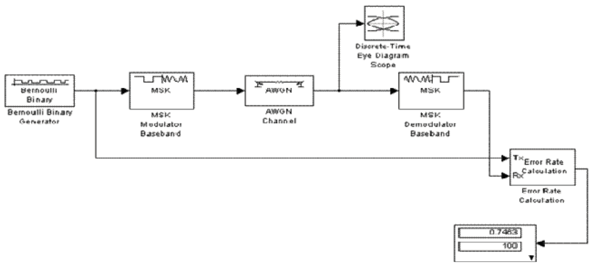

Figure 7: The Block diagram of MPSK Modulations

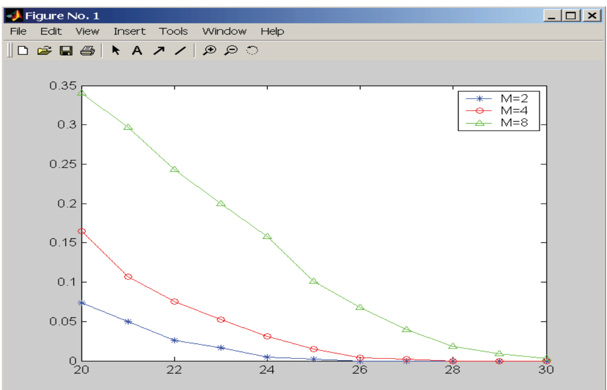

Figure 8: The BER versus SNR for MPSK

Figure 8 shows, for MPSK, as the value of M increase the BER increase. So, MPSK is better in term of BER when the value of M is small.

IV. RESULTS AND DISCUSSION

A 13-item survey was administered to 57 Information Technology undergraduate students. The survey tapped students' reactions to using Matlab with Simulink for learning and understanding digital and analog modulation concepts. The convenience sample of participants responded to the survey, which was based on the following, 5-point Likert scale: 5 = Strongly Agree; 4 = Agree; 3 = Somewhat Agree; 2 = Disagree; 1 = Strongly Disagree. As can be seen from Table 3, students expressed a general consensus towards their agreement of the benefits of incorporating Matlab with Simulink in their course. Most of them, for instance, claimed that the Matlab with Simulink component was very useful for helping them understand the theoretical aspect of the course, thereby increasing their knowledge base of the subject matter.

TABLE III. Descriptive *STATISTICS (N=57)*

Variable	Min.	Max.	Mean	SD
Knowledge before 1	1	5	3.02	1.009
Knowledge after 2	2	5	4.14	.766
Attitude 3	2	5	3.71	.762
Understanding 4	2	5	4.04	.731
Learnmore 5	1	5	3.69	.979
Easy to use 6	11	5	3.68	1.003
Approving 7	1	5	3.50	.885
Simulation experience 8	1	5	3.55	.807
Learning experience 9	1	5	3.68	.917
Interact 10	2	5	3.81	.693
Educational 11	2	5	3.89	.673
Comfortable 12	2	5	3.86	.718
Satisfied 13	2	5	3.74	.813

Independent Samples T-Tests were run to investigate differences between the 2006 and 2007 cohorts in terms of how they perceive the usefulness of Matlab with Sumilink. As can be seen in Table 4, higher means were observed for the 2007 students. This group of students held more favorable views about the utility of Matlab with Sumilink in their course. For example, compared to their 2006 counterparts, the 2007 cohort felt more strongly that Matlab with Simulink was easy to use (mean = 4.41), helped them understand the course much better (mean = 4.45), and that their knowledge has now increased as a result of using Matlab with Sumilink (mean = 4.55).

TABLE IV. T-Test (N=57)

Variable	N	Year	Mean	SD
Knowledgebefore 1	35	2006	2.89	1.051
	22	2007	3.23	.922
Knowledgeafter 2	35	2006	3.89	.128
	22	2007	4.55	.127
Attitude 3	35	2006	3.57	.118
	20	2007	3.95	.185
Understanding 4	35	2006	3.77	.117
	22	2007	4.45	.127
Learnmore 5	34	2006	3.32	.945
	21	2007	4.29	.717
Easy to use 6	35	2006	3.23	.154
	22	2007	4.41	.142
Approving 7	33	2006	3.27	.164
	21	2007	3.86	.143
Simulation experience 8	34	2006	3.32	.138
	22	2007	3.91	.146
Learning experience 9	35	2006	3.40	.154
	21	2007	4.14	.159

Interact 10	35	2006	3.57	.111
	22	2007	4.18	.125
Educational 11	35	2006	3.63	.101
	22	2007	4.32	.121
Comfortable 12	35	2006	3.63	.117
	22	2007	4.23	.130
Satisfied 13	35	2006	3.43	.131
	22	2007	4.23	.130

A. Internal consistency reliability

A Pearson correlation matrix of the 13 Matlab with Simulink questionnaire items was run yielding a Cronbach's alpha coefficient of .91 (α = .91). The 13-item questionnaire was then subjected to factor analysis using principal axis factoring to extract the underlying factors.

B. Factor Analysis

Data from the 13-item, Matlab with Simulink questionnaire was analyzed using principal axis factoring (SPSS 14.0) to extract the underlying factors. Principal axis factoring is preferred over the principal components analysis method, which is the default option in some statistical programs including SPSS. Since it is assumed that in principal components analysis all variability in an item ought to be used, it is advantageous to use the principal axis factoring method through which the researcher can only use the variability in an item that it shares with the other items [20]. The number of factors to be extracted was based on minimum eigenvalues of 1.0 and minimum loadings of .45 of individual items under each factor. The Kaiser-Gutman procedure, through which only factors with eigenvalues of one or greater are selected, is the most often used method to determine the number of factors [21]. The varimax rotation method produced a two-factor solution, accounting for almost 62% of the total variance (see Table 7). Varimax rotation was employed because it is a type of orthogonal rotation that mathematically ensures that the resulting factors are uncorrelated with each other [21]. This is important since in exploratory factor analysis, the researcher does not know the number and the types of factors that exist, let alone whether or not they are correlated [19].

1) Factor 1: Factor 1 consisted of eleven items from the Matlab with Simulink questionnaire. The following eleven items loaded on factor 1(Table 5):

TABLE V. Eleven items from the Matlab & Simulink Questionnaire

	Loading
My overall attitude towards Matlab with Simulink	0.65
Matlab with Simulink is a useful tool for understanding course content.	0.62
If Matlab with Simulink is available in the future, I will use it to learn more about it.	0.77
Matlab with Simulink is easy to use.	0.66
Most people who are aware of what I'm studying would approve my using of Matlab with Simulink in the future to learn.	0.72
I have experience using computer-based simulation tools	0.64
I like Matlab with Simulink being part of my learning experience.	0.8
I am inclined to use Matlab with Simulink because it increases my ability to interact with the course content.	0.76
I am inclined to use Matlab with Simulink because of its educational benefits.	0.71
I feel comfortable when using Matlab with Simulink to learn course content because it enables me to learn	0.66
I feel satisfied with my learning experience using Matlab with Simulink.	0.76

2) Factor 2: Factor 2 consisted of two items from the Matlab with Simulink questionnaire. The following two items loaded on factor 2 (Table 6):

TABLE VI. Two items from the Matlab & Simulink Questionnaire

	Loading
Before using Matlab with Simulink, my knowledge of course content was:	0.51
Now, my knowledge of course content is:	0.79

In sum, results of the factor analysis portion of this study suggested two components that characterize the School of IT students' perceptions and attitudes towards the benefits of incorporating Matlab with Simulink into the course curriculum. Factor 1 can be labeled "Motivation" since all of the items that loaded onto it are likely to contribute to learners' engagement and motivation in the classroom because of the Matlab with Simulink component. The two items that loaded on factor 2 are strictly related to students' knowledge level before and after their experience with the Matlab Simulink. Therefore, Factor 2 can be labeled as "Knowledge Competence" (See Table 8).

TABLE VII. Principal Axis Factoring (13 questionnaire items)

Factor	Eigenvalue	% of Variance	Cumulative %
1	6.749	51.915	51.915
2	1.305	10.038	61.953

TABLE VIII. Factor Structure

Factor	Label	Eigen -value	Variance	Cumulative Variance
1	Motivation	6.749	51.915	51.915
2	Knowledge Competence	1.305	10.038	61.953

V. CONCLUSION

In this paper, the approach utilizes Matlab packages, Simulink, and Communication Blockset to simulate analog and digital modulation techniques avoiding the derivation of any mathematics formulations. A survey that was distributed to 57 Information Technology students who were taught using this approach showed a high level of satisfaction in understanding all modulation concepts. As can be seen from the survey results, students expressed a general consensus towards their agreement of the benefits of incorporating Matlab with Simulink in their course. Most of them, for instance, claimed that the Matlab with Simulink component was very useful for helping them understand the theoretical aspect of the course, thereby increasing their knowledge based on the subject matters.

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Session 04B Area 4: Active Learning - Project based learning

Research-based approach application for electrical engineering education of bachelor program students in Riga Technical University

Chaiko, Yelena; Kunicina, Nadezhda; Patlins, Antons; Ribickis, Leonids; Zhiravecka, Anastasija

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Learning by doing in Project Management: Acquiring skills through a collaborative model

Cobo-Benita, José Ramón; Ordieres-Meré, Joaquín; Ortiz-Marcos, Isabel; Pacios-Álvarez, Antonia

Technical University of Madrid-UPM (Spain)

Integrating Teams In Multidisciplinary Project Based Learning in Mechanical Engineering

Márquez, Juan J.; Martínez-Muneta, Mª Luisa; Pérez, Jesús M.; Romero, Gregorio

Technical University of Madrid-UPM (Spain)

A Project-Based Learning Approach to Teaching Power Electronics

Arias, Manuel; Lamar, Diego G.; Miaja, Pablo F.; Rodríguez, Alberto; Rodríguez, Miguel; Sebastián, Javier

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Research-based approach application for electrical engineering education of bachelor program students in Riga Technical University

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Abstract—***Research based approach in education is important for engineering specialties. The implementation of this approach is interesting for students also. The research possibilities involve all level of education process: pupil's interest is higher, average mark of students is increasing; the number of graduate students is increasing with introduction of research-based approach.***

Keywords- Research-based approach, electrical engineering , bachelor program

I. INTRODUCTION

The education in Power and Electrical Engineering is set as priority in many countries, because people have to find ways to substitute petroleum and natural energy recourses, which are decreasing in the world each day, to introduce more efficient and safe approaches to the use of present energy resources and significantly decrease unnecessary losses of energy. In different countries, there are large discussions about the rational use of power resources: gradual transition to bio-fuel, use of hydrogen power in transport systems, development of cars with hybrid transmission and electro mobiles.

The countries of the European Union also have declared the beginning of the power engineering revolution towards the same purposes like the same program in the USA does.

The existing contacts with other universities in Europe allow wide use of Erasmus students exchange programme, especially during the process of final papers preparation, such as bachelor and master thesis. According to statistical data from Ministry of Education and Science the number of students of Riga Technical University studying abroad in 2008 was 89 (table 1). The study programme "Computer control of electrical technologies" is popular at international level, at the present moment five of international undergraduate students are studying at our institute Also students from Latvia are going abroad, for example Vladimirs Skopis and Julija Soboleva the students of professional bachelor program within the frames of Erasmus programme, and now they study in Sweden in King Technology institute / Kungliga Tekniska Högskolan. By financial support for master studies in Germany from German academic exchange centre (DAAD – Deutscher Akademischer Austausch Dienst) this year awarded Armands Senfelds and Edgars Ivanovs .

It is great opportunity to have an experience in international groups, which allows having an international carrier in future. This is a great benefit from Bologna process introduction.

TABLE I. STATISTICAL DATA FROM MINISTRY OF EDUCATION AND SCIENCE THE NUMBER OF RIGA TECHNICAL UNIVERSITY STUDENTS STUDING ABROAD (2008)

Germany	20	Spain	6
Italy	13	Austria	4
Sweden	12	Czech Republic	4
Portugal	10	France	2
Denmark	10	UK	1
The Netherlands	6	Finland	1
Total 89			

The education in RTU covers all steps of academic and professional high education (figure 1) in full time and part time groups.

A leader in Latvia in the electrical engineers education and training is Riga Technical University (RTU), Faculty of Faculty of Power and Electrical Engineering, Institute of Power engineering, Institute of Industrial electronics and electrical engineering and Environmental engineering Institute.

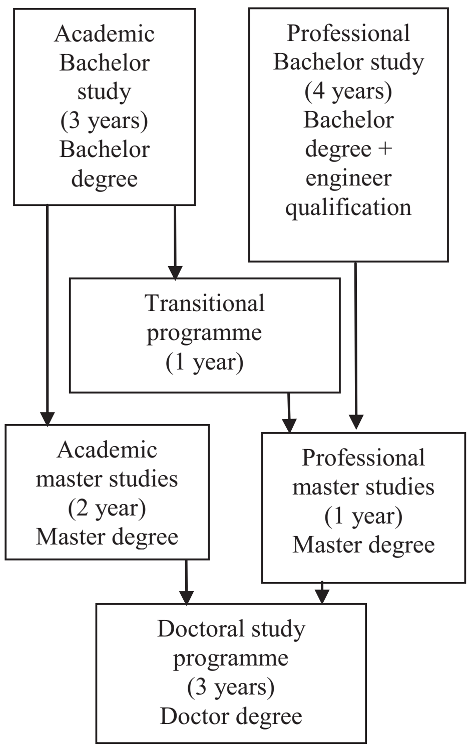

Figure 1. Study levels and education duration for study programme computer control of electrical technologies

Principles of integration of educational process and scientific researches are radical ways of improvement of quality of preparation of electrical engineers education and training in efficient energy production and consumption. The training and research integration principles are presented as efficient way for training of energy-and-sources-saving specialists. Faculty of Power and Electrical Engineering in RTU provides several study programs: Electrical and Power Engineering; Computer Control of Electrical Technologies; Environmental Engineering. Each year more then 250 students enter for the first year studies.

II. Description of education structure

The study programme computer control of electrical technologies is a research based educational programme. Every day research activities are an integral part of the routine work of the staff of the Institute of Industrial electronics and electrical engineering (IEEI). The group of seven senior researchers are realizing research process in the institute. For that branch of activities IEEI has been legally registered in the state as a scientific institution. This allows applying for European structural funds support programs for modernisation of institution research equipment and financing of young researcher's attraction. Based on the research the staff of the Institute proposed sixteen new patents in 2008. During the same period of time in the institute twenty one patents are submitted. The Institute has published four scientific monographies and forty seven scientific publications in proceedings of international conferences abroad. The students of the Institute defended twenty seven bachelor theses, fifteen engineer projects, twenty three master theses and three PhD theses.

The IEEI working strategy is to fulfil the program „Computer control of electrical technologies" in the fields of industrial electronics and electrical engineering with the specializations in power electronics, adjustable electric drive, automatization of electrical technologies and electric transport, to develop scientific investigations in the field of industrial electronics and electrical engineering, realizing the program, which meets the needs of industry and the graduates of which are competitive at the world labour market.

The education in power engineering on one hand covers education in Energy production and transmission as a study program of Electrical and Power Engineering, on the other hand energy consumption and control in study program Computer Control of Electrical Technologies (figure 2) and possibilities of the decreasing of the impact on the environment in study program Environmental Engineering.

Figure 2. Bachelor students are examining regulation theory application for electrical technologies, using computer simulation

The students of study program Computer Control of Electrical Technologies obtain practical skills and theoretical knowledge in control, designing and operation of the computerised electric technical devices. For successful students with good knowledge of foreign languages (English or German), IEEI provides a possibility of partial training abroad.

The level of technology development demands high qualification and effectiveness of education in the field of electrical engineering.

The number of students of different levels and directions of the studies (including the students of evening and extramural department) is presented in table 2.

TABLE II. THE NUMBER OF STUDENTS OF DIFFERENT LEVELS AND DIRECTIONS OF THE STUDIES

Levels of studies, programs and directions	Number of students total	Nr of graduates
Bachelor studies total	180	27
Bachelor studies (B)	56	13
Bachelor studies (C) profes.	124	14
Master studies (acad)	7	0
2 level professional post-bachelor studies (G)	57	23
Students total amount	244	50
Doctoral studies in „Computer Control of Electrical Technologies"	*22*	*3*

Academic studies last three years, during this time the students have basic courses and are to defend bachelor thesis at the end.

During the professional studies the students have in addition practical working experience at industrial enterprises. This industrial practice lasts 6,5 months.

The industrial practice of students (figure 3, 4) is the major part of process of preparation of highly skilled specialists. Practice will be organised in various branches of a national economy at the leading industrial enterprises, firms and establishments of the Latvian republic. According to the program Computer Control of Electrical Technologies, during the industrial practice the student's master practical skills in the work with electric motors and systems, and in automatic control of such systems. Main principles and ways of automatic control, and also possibility of automation of industrial technological process by means of computer management accustom, there is a development of modern techniques, the students receive practical skills in installation and operation of new modern devices and elements in manufacture.

Main areas for research results application are the companies, which produce electrical and electromechanical equipment as well as in designing, process optimisation and service processes, in electrical engineering and technologies supervision and control.

The skills received in the course of an industrial practice, and also materials of any particular production, the device or object of automation, can be used for writing bachelor, engineer or master degree works. The content of practice, and also the terms of it are defined according to the confirmed curricula and programs.

Figure 3. Bachelor students Maris Gureckis, Ugis Sirmelis are studying industrial power drives in Latvenergo division TEC-2.

Practice is provided both for the professional bachelor and master programs. In programs of the professional bachelor "ECO0" the volume of a practical training is 26KP that in a time equivalent makes work at the place of practice within 16 weeks or 26x16=416 hours. Since 2009./2010 academic year this practice, in the programs of day training of students is included in the 6th semester with the volume of 5KP (80 hours), in the 7th semester with 12KP (192 hours), and in the 8th semester with – 9KP (144 hours).

Figure 4. RTU supervisor prof. asoc. A. Ziravecka, Supervisor from industrial partner U. Anitens and student A. Shapovalovs at experimental results monitoring of relay systems Latvenergo division at Jelgava city.

If a student has completed the training under the academic program and starts further training under the master program then he/she is enlisted into the transitive program "EGOB" and in the first half of the year passes practice with volume 14KP, and in the second - with 12KP, completing thus the necessary qualification of the professional bachelor practice of 26KP.

Both in the program of the professional bachelor, and during the transitive master year, the student, mainly, pays attention to gathering of a material for the future engineering project the defending of which provides an obtaining of professional qualification.

The purpose of the practice:

- to apply practically knowledge and the skills received in the course of training under the program of a professional master "Computer Control of Electrical Technologies";

- to get an acquaintance for students with work of the enterprises, and teachers with requirements of the enterprises;

- to involve into the process of formation the organisations-partners, organising practice outside the educational institution;

- to provide cooperation with large, middle and branch small enterprises.

III. Project-based learning methodology

The use of project-based learning (PBL) [1] method is the important methodological issue to get sustainable development of economy in Latvia. The RTU is the main higher education structure in Latvia, according to the total amount of students, so the technical development of Latvia is strongly related to the level of education in Riga Technical University. The PBL introducing in RTU is extremely important, for developing innovations, and technical progress in Latvia.

PBL [1, 2, 3] in general provides complex tasks based on challenging questions or problems that involve the students' problem solving, decision making, investigative skills, and reflection that include teacher facilitation, but not direction. Project Based Learning is focused on questions that initiate students to encounter the central concepts and principles of a subject hands-on.

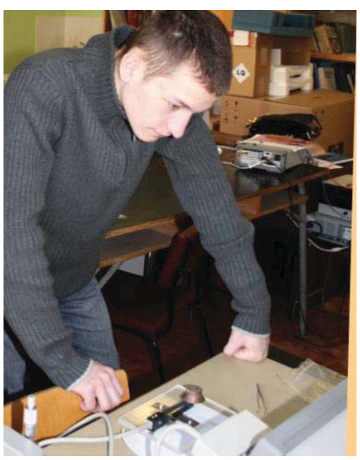

Figure 5. A. Morozovs is now a Bachelor student of study programm Computer Control of Electrical Technologies experiment on material dielectric density measurement in RTU

The main PBL advantages in general [2] are that it: overcomes the dichotomy between knowledge and thinking, helping students to both "know" and "do."; supports students in learning and practicing skills in problem solving, communication, and self-management; encourages the development of habits of mind associated with lifelong learning, civic responsibility, and personal or career success; integrates curriculum areas, thematic instruction, and community issues; assesses performance on content and skills using criteria similar to those in the real work world, thus encouraging accountability, goal setting, and improved performance; creates positive communication and collaborative relationships among diverse groups of students; meets the needs of learners with varying skill levels and learning styles; engages and motivates bored or indifferent students. The main problems of introducing the PBL in RTU are changing the way of thinking of academic staff and students, talking about technical problems to solve it.

IV. Project-based learning methodology application

The project based methodology application within the frames of study programme Computer Control of Electrical Technologies starts before studies in RTU. IEEI has cooperation agreements and experience to involve in research process also pupils from secondary schools. Pupils during annual project week make research, using RTU facilities, equipment and staff consultation. During the project realisation Riga Ukrainian 12th school pupil Aleksandrs Morozs made a research in dialectical features of materials and used RTU staff experience and facilities. Now he is the 1st year student of the considered programme (figure 5).

TABLE III. The number of applications for the 1st year full time program in 2009

Study program	City	State financial places	Priority	Number of applications
REBO0	Rīga	20	1	25
			2	48
			3	8
RECO0	Rīga	35	1	38
			2	15
			3	11
VEBO0	Ventspils	3	1	2
			2	5
			3	1
LECO0	Liepāja	6	1	7
			2	4

There is also quite a large difference in pupil's interests in academic and professional studies. The tendency of last 3 years is that application amount of professional study programme is higher than in academic programme Tables 3 and 4). In code of programme REBO0 means: is Riga Electric Bachelor (Academic) O Computer control study programme 0 number of group; in other code RECO0: C means Bachelor (Professional). L and V means education place in Latvian cities Ventspils and Liepaja.

TABLE IV. THE NUMBER OF ACCEPTED STUDENTS FOR THE 1ST YEAR FULL TIME PROGRAM IN 2009

Study program	City	State financial places	Priority	Number of registrations
REBO0	Rīga	20	1	8
			2	20
			3	3
RECO0	Rīga	35	1	18
			2	7
			3	1
VEBO0	Ventspils	3	1	2
			2	3
			3	1
LECO0	Liepāja	6	1	2
			2	4

Main advantage in pupil's questionnaires is a possibility to have practical skills and choose place of future job during practice time.

This thesis was used during pupil's attraction seminars from 2005 till 2008.

The practical experiment in education means have been shown in pupils attraction seminars in secondary schools and this approach allows to attracts "technically minded" pupils.

Figure 6. Students at factory REBIR (Rezekne, Latvia)

The research based approach education means not only writing thesis, but also visiting industrial companies. During the studies students take part in various cooperation projects with industrial partners. The first steps for Bachelor students are visiting the partners and preliminary introduction into industry specific field and organization (Figure 6).

The next step is to choose an industrial partner for practice. All the work during practical time including the tasks of the students and their reports about the practice is organized in the way that it brings scientific benefit for the industrial partners. The RTU facilities for experimental work and specific research is of huge interest not only for day time students, but also for part time students, which mainly starts their education after colleges and many years of experience at industries companies.

As the result of research students annually have RTU scientific conference in April. Every year the best students' works are nominated in RTU senate, and one student from each section will be named and receive gift. It is the first time, when the Cinder's named scientific organization activity is focused on RTU that means each year the interest in researchers, students and companies is increasing. This year, conferences are organized in computer control of electrical technologies, intelligent electrical transport programming and intelligent electrical transport modelling section. There were more then 57 students and Riga State Gymnasium pupils' scientific works results presented.

Figure 7. Student A.Braufmans is defending his bachelor work demonstrating physical results

The use of the project based approach allows adding also Bachelor and engineering projects with practical application (figure 7).

During the studies students also have been involved in research projects, the involved students are specially pointed as a criterion for support of RTU internal annual research projects. Also international cooperation projects mainly at doctoral studies level, but also some bachelor students are involved (figure 8).

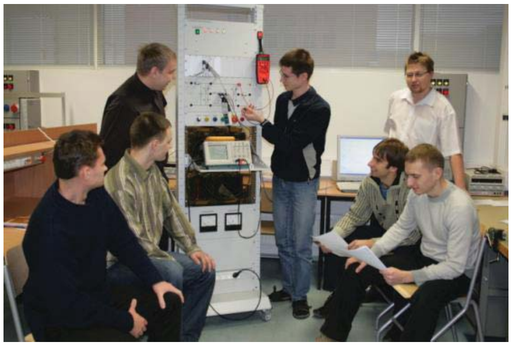

Figure 8. Students during the period of school for post-graduate student

V. AWARDS

The best students' works annually are nominated at various competitions. Industry partners and state organisations support best student's research.

Figure 9. Prof. I. Rankis (standing the fourth at the right), prof. L. Ribickis (standing the fifth at the right) at the ceremony of winners awarding of organized by Siemens competition „Werner fon Siemens Excellence Award", M.sc.ing. M. Pletnova (sitting the second at the right) and Dr.sc.ing. A. Vitols (sitting in the middle).

Many students within last three years have received a special prize in honor of Werner fon Simens for the best master and doctor's thesis in the sphere of the exact and technical sciences. Many students IEEI have been awarded with this honourable prize: A. Vitols (Figure 9) for doctor's thesis „Research of the power-electronic converter for bidirectional energy flow of traction substations", O. Krievs for doctor's thesis "Investigation and development of control systems for active filters of power electronic converters" I. Rodionova for doctor's thesis "Investigation of the effectiveness of AC electric trains direct current electric drives"; M. Pļetņova for her master thesis " Main Tasks and Realization of Automation of Oil Products Storage and Transportation ", A. Vilks for master thesis " Investigation of Possibilities to Improve Electric Magnetic Compatibility of Thyristors Regulated Reactors ".

IEEI students regularly participate and are being awarded in competitions of degree works which is organised every year by the Riga Dome, the Latvian fund of formation, the Latvian association of electroenergetics and power builders, company Latvenergo and ABB Ltd.

VI. CONCLUSION

The application of project based learning approach in electrical engineering studies is the main instrument to reach acceptable level of specialists and, as a consequence, of industry in Latvia.

The research possibilities involve all level of education process: pupil's interest is higher, average mark of students increase; the numbers of graduate students are increased after introduction of research-based approach.

At least seven activities should be continuously realized for the successful organization of the engineers and other specialists educational and training process: education should be continues, from school, the young researcher centres should be supported, the competitions and other pupils attractions should be used to attract people into engineering science; attraction of talented pupils and explanation for teachers should be made continuously; students' scientific conferences should be organized; competitions with significant prizes should be organized for pupils and students.

The analysis of case study at IEEI, which is a leader in RTU in project-based learning application, shows that such strategy application could give a two times increasing of the number of students at the program that in its turn increases the flow of financial resources of the institution more than two times as well as it can significantly improve the quality of education and the range of students' and further specialists' knowledge and skills.

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Learning by doing in Project Management: Acquiring skills through a collaborative model

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Abstract— **This paper presents a teaching approach for an undergraduate course of project management under the learning by doing paradigm. The course experience as a whole is presented, including planning aspects for all scheduled activities, are provided later. The definition of the project is provided, as well as its specific details for practical project work, the main educative instrument of the course, in order to bring out the most relevant aspects of the approach. These include improving the learning process by means of a collaborative model and details of the assessment process that make continuous improvement possible. Detailed research to evaluate the effect of students' previous work experience of this learning model is also considered in this paper.**

Keywords-project management skills; collaborative groups; interdisciplinary groups; engineering education; learning by doing formatting.

I. Introduction

This paper presents a 'learning by doing' approach related to a course in the project management of engineering projects, which is offered in the final academic year of the Industrial Engineering Degree at Universidad Politécnica de Madrid.

The teaching approach involves a combination of several topics in an endeavour to reinforce the learning process itself. These topics are:

- Practical work focused on managing a real project, mainly in its beginning stages (preliminary scope of the work, feasibility analyses, technical and tactical scope of the work, design, documentation and customer presentation).
- Competition among teams of students.
- Transforming theoretical course material from a time-oriented presentation to a practical presentation of contents that enables them to become of direct use in practical work.
- Combining different roles and responsibilities within each student team in order to improve the learning process that results from internal discussions in which students adopt different roles.

The subject of the project was chosen to ensure that:

- Several disciplines are involved.
- Different solutions are possible.
- Integrative solutions must be found in order to present a coherent solution to the customer.

The teacher has two different roles in order to foster student learning from the training. The first role is that of an external consultant to the student team. The second role is as a customer representative, who is able to negotiate (i.e., make decisions or agree to compromises on behalf of the customer), if required.

For much of prehistory, educational methods were largely informal. Children imitated the behavior of others or modeled their behavior on that of their elders, learning through observation and play. In this sense, the children were the students, and the elder was the teacher. A teacher creates the course materials to be taught and then puts them into operation. Pedagogy is usually defined as the different methods by which a teacher can teach. It is the art or science of being a teacher, generally referring to strategies of instruction or style of instruction.

There are several methodologies available for teaching engineering courses, but, according to ANECA [1], the agency in charge of monitoring the educational system at the university level in Spain, more than 90% of engineering courses uses a delivery strategy based on lectures. The purpose of a lecture is to clarify information for a large group in a short period of time. Lectures require a great deal of time for preparation and need to be supported by various audio-visual materials. The lecture is an instructor-centered methodology.

Although the lecture strategy has such advantages as productivity in content delivery and its suitability for specific topics like project management, it also presents difficulties. These difficulties are related mainly to the knowledge, which has a high degree of practical application, and specific context skills, such as leadership skills, negotiating skills, etc., which are usually perceived by students to be abilities that are acquired or developed outside of school. In addition, students of engineering greatly prefer technical content to managerial content, which they perceive to be potentially useful, but provided only after they have completed the educational process. All of these elements serve to strengthen students' passive attitude.

In order to manage this context, some particular improvements have been designed [2], implemented and tested. They were motivated by a desire to foster a greater engagement of students as well to reinforce the learning process itself [3]. These special add-ons included the immediate use of most of the theoretical components presented, team competitions, team work, and negotiation [4].

As described later in this paper, this study can be viewed as the construction of an applied learning environment [5] under a paradigm of learning by doing [6] in which concepts and tools are required to develop practical work in a competitive context. A convenient conceptual framework is provided before theory class is runned under a discussion approach. The purpose of a discussion is to solicit student participation and involve the student in content transmittal. Discussions are usually limited to small groups and require considerable time. However, the discussion method requires little audio-visual support. It promotes understanding and the clarification of concepts, ideas, and feelings. There are numerous variations. The discussion method can vary from a teacher-centered approach to a student-centered approach. Examples of specific methods that can be employed include role playing, debates, panel discussions, reviews, supervised study, brainstorming, buzz groups, idea incubation, tests, show-and-tell, worksheets, conferences, and interviews. In this particular teaching approach), a role playing approach was usually selected, although the relatively high number of students to manage was a challenge. An additional reason to use the role playing approach is that students must become very accustomed to these concepts for immediate practical application in competitive practical projects. In creating a suitable environment in which to use the acquired knowledge, specific asynchronous events that impact a project's lifecycle are introduced [8].

All scheduled activities need to be estimated in terms of student effort in accordance with ECTS criteria. Satisfying this requirement for the project management course produced the following distribution, assuming duration of 14 weeks per course (Table I).

TABLE I. DISTRIBUTION OF STUDENT EFFORT IN THE PROJECT MANAGEMENT COURSE

Task	In class effort (Per week)	Out of class effort (Per week)	Total effort (Per course)
Reading course material	0 h	2 h	28 h
On line quiz relative to theoretical reading material	0 h	0,25 h	3,5 h
Class discussion	1 h	0 h	14 h
Individual work	0 h	1,5 h	21 h
Software practical class	0,5 h	0 h	7h
Practical project Development	0,5 h	5 h	63 h
Public presentation	0,05 h	0,1 h	2,1 h
Test	0,25 h	1h	17,5 h
Total	2,3 h	8,85h	156,1h

Like the time distributions of other courses and, because the course has been given a grade of 6 ECTS and one ECTS means 27h at Universidad Politécnica de Madrid, the total time available is 162h. This includes a float of 4% as a safety factor since the estimate was based on averages.

Investigating the outperformance of teams according to their internal structures [7] was of additional interest. In order to investigate the effect of previous work experience in developing the real project, two different teams were created, the first consisting entirely of young students who had no previous work experience and the second consisting of students who possessed significant previous work experience.

An additional interest for this research is to measure the instructor's effort. In such way, specific activities for theoretical learning processes and practical ones are presented (Table II).

The rest of this paper is focused on presenting the relevant aspects of the development of a practical project, as the latter is the driving force of the PBL approach chosen. Firstly, previous experiences in teaching project management by use of a 'Project-based learning' methodology is recalled, as this is the easiest way of identifying innovations to include in the learning approach presented here. This is the objective for section II.

Later, the project definition and implementation details are presented, bringing up the most relevant aspects of the experience, like details of assessment of the process to make continuous improvement possible or improving the learning process by a collaborative approach. This is the goal of section III.

The next section is dedicated to a discussion of the results of the experience, including learning planning, learning development, a comparison to classical lecture-based learning models and an overall score. Also discussed is how these results are transformed into learned lessons as feed-back. Finally, the last section presents the main conclusions and future plans.

TABLE II. DISTRIBUTION OF INSTRUCTOR'S EFFORT IN THE PROJECT MANAGEMENT COURSE

Task	Theoretical effort (Per week)	Practical effort (Per week)
Preparing and updating course materials (syllabus, quiz and case studies)	3h	
Class discussion	1h	
Scoring four individual assignments	4h	
Test definition and evaluation	1h	
Practical case definition		1h
Monitoring the project evolution and reporting		2h
Scoring the practical work including public presentation		2h
Individual mentoring	3h	3h
Total	12h	8h

II. PROJECT-BASED LEARNING AND COLLABORATIVE TEAMWORK IN PROJECT ENGINEERING

There is a shift in emphasis in engineering education from professional skills to process skills [9]. These skills include problem analysis and problem solving, project management and leadership, analytical skills and critical thinking, dissemination and communication, interdisciplinary competencies, intercultural communication, innovation and creativity, and social abilities. PBL has proved to be an excellent method for development of new forms of competencies [10][11].

Research has shown that students retain minimal information in the traditional didactic teaching environment and frequently experience difficulty in transferring the acquired knowledge to new experiences [12]. A PBL environment enables students to draw upon their prior knowledge and skills, brings a real-world context to the classroom, and reinforces the knowledge acquired by both independent and cooperative group work [13].

PBL is a model in which learning opportunities are organized around projects [14]. According to the definitions found in PBL papers, projects are complex tasks that are based on challenging questions or problems that involve students in design, problem-solving, decision making, or investigative activities. They give students an opportunity to work relatively autonomously over extended periods of time and culminate in realistic products or presentations [15] [16] [17]. Other defining features of projects that have been found in the literature include authentic content, authentic assessment, teacher facilitation without direction, explicit educational goals [18], cooperative learning, reflection, and incorporation of professional skills [19].

Several criteria define what a project should have in order to be considered an instance of PBL [20]. The five criteria are centrality, a driving question, constructive investigation, autonomy, and realism. The first criterion is that PBL projects must be central, not peripheral, to the curriculum. In PBL, the project is the central teaching strategy. Students encounter and learn the central concepts of the discipline by means of the project. The second criterion is that PBL projects must be focused on questions or problems that "drive" students to encounter the central concepts and principles of a discipline. The definition of the project (for students) should be so crafted that a connection is formed between activities and the underlying conceptual knowledge that one might hope to foster [21] [22]. The third criterion is that projects must involve students in a constructive investigation. An investigation is a goal-directed process that involves inquiry, knowledge building and resolution. Investigations may take the form of design, decision-making, problem-finding, problem-solving, discovery, or model-building processes. However, in order to be considered as a PBL project, the central activities of the project must involve the transformation and creation of knowledge (by definition: new understanding, new skills) on the part of students [23]. The fourth criterion is that projects must be student-driven to a significant degree. PBL projects incorporate a good deal more student autonomy, choice, unsupervised work time, and responsibility than traditional instruction and projects. Finally, the fifth criterion is that projects must be realistic and not school-like. Projects should have characteristics that give them a feeling of authenticity to students. These characteristics can involve the topic, the tasks, the roles that students play, the context within which the work of the project is carried out, the collaborators who work with students on the project, the products that are produced, the audience for the project's products, or the criteria by which the products or performances are judged. Reference [24] was the first to make a distinction between academic challenges, situation challenges, and real-life challenges. PBL incorporates real-life challenges where the focus is on authentic (not simulated) problems or questions and where there is a possibility that solutions will be implemented.

In PBL, the project is the central teaching strategy. Students encounter and learn the central concepts of the discipline by means of the project. There is a longstanding tradition in schools of "doing projects," incorporating "hands-on" activities, developing interdisciplinary themes, conducting field trips, and implementing laboratory investigations [25].

Research on PBL can be undertaken to: (1) make judgments about the effectiveness of it (collective evaluations), (2) assess or describe the degree of success resulting from implementation or performance of Project-Based Learning (formative evaluation), (3) assess the role of student characteristics in PBL effectiveness or appropriateness (aptitude-treatment interactions), or (4) test a proposed feature or modification of Project-Based Learning (intervention research) [20]. Moreover, there are at least three traditions from which PBL research and practice seem to emerge. They are: (1) Outward Bound wilderness expeditions [26] [27], (2) postsecondary models of PBL [22] [28], and (3) university-based research in cognition and cognitive science applications [29] [30] [31].

The inclusion of real-world problems in engineering education reinforces concepts and improves learning in ways not available with traditional lecture methods or predefined case problems [32]. Students develop problem solving skills, project management skills, communication and teamwork skills, and a sense of professionalism from such experiences.

III. EXPERIMENT AND ASSESSMENT PLAN

A. Project definition

The learning approach presented here concerns the development of a real engineering project by groups' competitive assignments. The main purpose of *playing to manage projects* is to move on from simply learning contents by heart to understanding, discussing and sharing in order to learn from experience.

The project proposed is multidisciplinary and unifying. Students come from nine different specializations: industrial management, manufacturing, energy, electronics, chemistry, construction, materials, mechanics and electricity. Each team member plays a different role, according to his/her specialization, skills or preferences. Each group appoints a project manager who has the authority to assign responsibilities and acts as the team spokesperson to communicate with the project's owner(s). The professor will play two different roles during the process – that of the project owner's representative who is ready to make decisions when required and also as an external consultant during the project follow-up meetings.

Each team will study the fundamental notions of Engineering Project Management and apply them to actual cases. Students will be required to define the scope of the project, assess its technical and economic feasibility, prepare a schedule and budget, and assume responsibility for cost management, conflict management, documentation management, follow-up controls, quality management, communication management, and, finally, completion of the project and the main conclusions.

In this study, the project owner is a European investment trust that is highly committed to the preservation of nature and the avoidance of any negative impact on the environment as a result of its investments.

Following an exhaustive analysis of the different investment opportunities, the trust has decided to embark on the construction of a non-hazardous industrial waste management plant. This new plant will be located in a highly industrialized area and will address the potential demand of nearby companies for waste disposal services. The project owner would like to see an analysis of the different alternatives for the construction of the plant, bearing in mind that the plant will be operated for a minimum of fifteen years and a maximum of twenty five years.

The strength of the proposed solution will be considered in the final assessment, as well as its conformity to existing legislation and the potential for waste treatment (the higher the better). Both the cost of the complete solution and its operating expense must be included in the budget. Finally, the engineering fees also must be included.

With regards to methodology, the students have at their disposal the theoretical materials needed to cause the project to move forward. In this learning experience, theory is subordinated to the requirements of practical sessions, both in sequence and content. The learner studies the contents and completes a questionnaire about the subject before a lecture or a project meeting takes place. For each knowledge area, the student submits an individual assignment about planning the scope, preparing an offer or taking a stance on a current topic in Project Engineering. All of these activities have been assigned specific time "costs" that count towards the final evaluation of the subject.

Two project teams were created for the case study that is under consideration, the teams are populated by ten to twelve members in order to have a fit management workload. Each project team represented a different consulting firm that had been asked by its client (the lecturer) to undertake an assessment of the project. In this context, the students apply the project management methodologies and techniques that they learned during the course to enable them to make a sound proposal that meets the client's terms (in time, resources, etc). The technical quality of the proposal, excellence of the presentation of the offer to the client and the team's performance in managing the project will count towards the final evaluation of the subject.

This participative model shifts the active role to the student, given the fact that he is the one who needs to solve the problem after he has validated his approach. Once the simulation of this collaborative, multidisciplinary model has been completed, it becomes clear that the proposed learning dynamics promotes the development of diverse knowledge competencies required to manage engineering projects: reach management, time management, resource management, cost management, communication management, risk management....In addition, the model fosters the development of collective skills, such as teamwork, conflict resolution skills, negotiating skills, leadership skills, self-control, creativity, commitment, motivation, etc. In short, the model permits the student to put into practice those skills that a project manager should possess. Finally, the student's impressions of this learning model with regards to planning, development and assessment are presented, as well as the methodology, resources employed and changes proposed to enhance the usefulness of the subject.

B. Development of the learning experience.

Each project team must meet for half an hour each week during which time the project manager reviews the work performed during the previous week that the plan had required. Also, tasks for the current week are agreed upon and scheduled.

All team participants must claim their hours spent in execution of assigned tasks. The project manager is responsible for managing the work to be done and reporting the hours used by all team members - 600 in this particular case. The efforts spent can also be reviewed. The limited time available for the weekly team meeting reinforces the need for skill in conducting meetings and leadership.

The Work Breakdown Structure, as well as internal deliverables (e.g., documents or products created by the team) are freely determined by the team itself with the only constrains being the total effort available and final products to be provided as a result of the work. This particular design improves the creativity and reinforces the contribution of the interdisciplinary groups to the common project, even when the interests that the students have in the project differ.

The role of the teacher is perceived to be that of an external consultant-agent, due mainly due to the effort expended in maintaining both profiles (consultant and owner representative). The specific management of the owner representative is an issue for team leaders. Team members' week-by-week progress in their work is the result of a combination of effort, use of their technical skills and the growth of group competencies (e.g., leadership, teamwork). This is an excellent way for monitoring the development of these competencies.

This approach puts emphasis on an active role for the students who must present a solution for a problem, after discussing it to assure them that it has been well thought out. During the learning experience, specific knowledge is applied by the students and various skills are reinforced, such as scope management, time management, resource management, communication management, both formal and informal, and risk management. The proposed approach also improves group competencies like teamwork, conflict management skills, self motivation, negotiating skills and competitiveness.

In order to evaluate the dynamic capabilities for quick answers by the teams, specific asynchronous events are introduced. For example, this might be an environmental regulation change that affects the project under development or a customer crisis that precipitates a sudden reduction in the size of the investment budget, which necessitates a significant change in the size or scope of the project. Such unexpected issues force the team to manage the situation by redefining the scope of the work, re-planning the work to be done or adjusting the previous plan It is an excellent way to see how the team manages a situation that can lead to loss of motivation, frustration, contempt for the customer or renewed motivation, or any combination of these elements, in order to win the competition. There is a possibility of observing a direct relationship between the attitude of team managers and internal team atmosphere. Obviously, there is a relationship between the team's internal atmosphere or morale and its productivity and the quality of the products that it delivers.

As the team needs to work in a multidisciplinary way, and nearly all team members have specific schedules due to their other engagements, it is appropriate to provide tools that allow for easy group work activities. To aid teams in this approach, a model [33] site was established, although teams are free to adopt other approaches, such as specific Google-groups. The model system provided is configured as group courses arranged in such a way that the contributions of one team are concealed from the members of other teams. These additional tools contribute towards improving members' skills for technological uses in the execution of projects.

The approaches carried out by the teams differ greatly. The team consisting of young students who lack professional experience invests a great deal of effort in devising the right scope and formulating logical alternatives. It functions as a real team with discussions, a common vision of the solutions and high commitment to project objectives. The other team, which consists of students who have previous professional experience, adopts a more individualistic approach. Only matters of coordination are handled at team meetings. The scheduling of individual tasks is conditioned in great degree by the experience of the participants. Significantly less time is given to developing the team. The homogeneity of people in teams and tasks was observed. It is noteworthy that some team members divided their attention between their employment and their studies. This makes it much more difficult to develop the team in ideal fashion.

IV. RESULTS AND FEED-BACK

A confidential survey was carried out during the last course week. Several groups of related questions were reviewed and scored on a Likert scale 1 to 5 (from fully unsatisfactory till fully satisfactory). As it is allowed to no answer some questions, 0 values mean no answer to that specific question. One chapter of the survey takes into account particular aspects related to the concerned methodology.

It becomes clear (Figure 1), that students prefer to read by themselves and to get their own feedback prior to attending a common discussion (answer X7_1) or to provide their own opinions in personal essays (answer X7_3). There is agreement in having an opportunity to develop a real project solution (answer X7_4), as well as activities like negotiation role plays (answer X7_5). Finally, greater support for the methodology used was obtained than for the more classical methodology, which is based on theoretical concepts plus some individual practical tasks, each of which is two hours in duration.

In addition to considering the feelings of students in regard to methodology, resources, services from teachers, the learning process and learning planning, a specific evaluation of the quality of the product was conducted.

X7_1. I agree with reading class material before the class and use that time for concept discussion.
X7_2. I agree with using the theory as a toolbox for development of practical projects.
X7_3. I agree with individual tasks that allow me to express my own opinions.
X7_4. I agree with the development of a practical project.
X7_5. I like to perform specific tasks like negotiation simulation.
X7_6. I like to learn specific software tools for project management.
X7_7. Overall, I prefer the current methodology, instead of the classic approach, which is much more oriented to lectures.

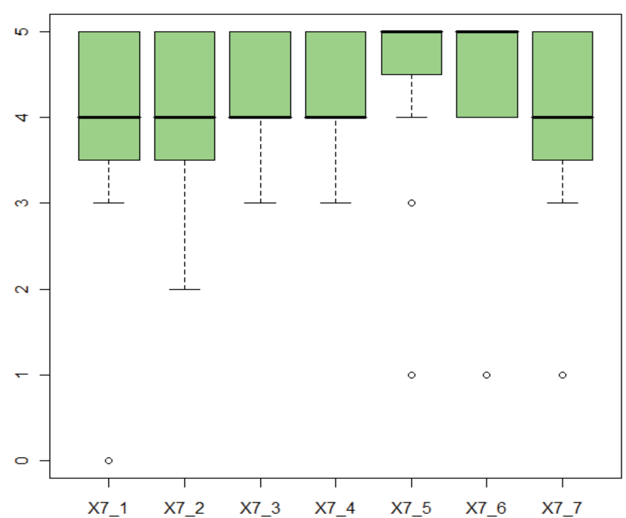

Figure 1. Boxplot of specific aspects of methodology.

From a technical point of view, both solutions were far removed from the professional viewpoints, due mainly to a lack of specific knowledge of the specific field. This can be used to introduce the subject of technology transfer solutions or, at least, to visit different solutions related to current problem. Another problem is the great differences between real costs and estimated costs for most cost categories. As most of the time was consumed in defining the problem and identifying alternatives, there was not enough time spent on the task of cost analysis.

A common strategy that the teams employed was to attempt to keep the owner's agent far from their design and solutions. The main drawback of this strategy is that, since the customer was not involved in intermediate decisions, the risk of a failure to fulfil customer's expectations becomes higher as the project nears its end. This was an important lesson that was learned.

By far, the most important problem identified by the students concerns the amount of time that the teams spent, although the number of hours claimed individually is consistent with the initially planned time (600 hours in this particular case).

Another specific problem not identified directly by students, but reported by teachers, is the project manager's lack of skills (i.e., the student acting in that role usually had more interest in technical questions than in managerial matters). This unfocused management normally leads to wasted efforts as the Work Breakdown Structure is produced later and there is no close tracking. A visible effect is a lower rating for teachers in practice classes (Figure 2).

It becomes clear that students are more comfortable with a fixed environment. They assign a lower rank to a noisy environment (Q3), (i.e., practical sessions where there is less structure and where time is managed by a project manager without the benefit of a plan provided by the teacher (see in Figure 2, answer for X6_3 against those for X6_2 and X6_4).

X6_1. There are enough teachers
X6_2. Teachers of theory do good work
X6_3. Practical class teachers do good work
X6_4. Overall, I agree with the performance of the teaching team

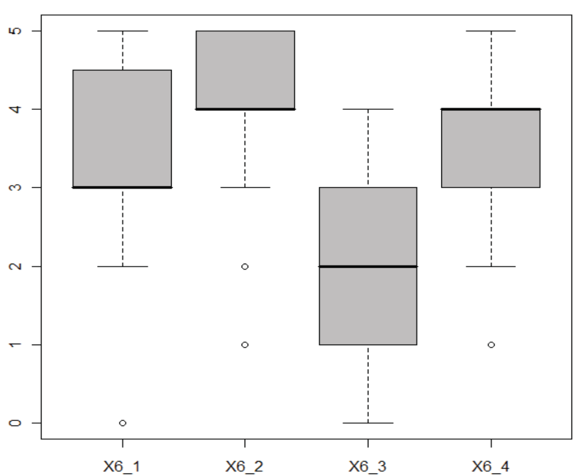

Figure 2. Boxplot of the perceptions of teacher performance

V. CONCLUSIONS AND FUTURE PLANS

As demonstrated, PBL is a method of instruction that challenges students to learn how to work cooperatively in groups in order to seek solutions to real world problems. These problems are used to engage students' curiosity and initiate the learning of the subject matter. PBL prepares students to think critically and analytically and to find and use appropriate learning resources (see Figure 3 below and particularly the answers to X4_5, X4_6 and X4_7).

This provides students with an opportunity to prepare for a professional life by practical training in coordinating a work group and working effectively as a member of a team. The independent research and learning aspects of the PBL provide the students with the skills necessary to identify, research and fill in the missing knowledge for the types of problems that they may encounter during their professional lives.

The purpose of this practice was not only to enable students to acquire technical knowledge, but also to open their minds and see what engineering project management is really about.

This experience has demonstrated that project-based learning is an effective way to effect student learning in the subject area of project management. In addition to detailed technical knowledge and performance skills, successful project management requires engagement, motivation, creativity and understanding. Interdisciplinary team projects offer many learning opportunities related to complex problem-solving, conflict resolution, and decision making, among others. The opportunity to develop these skills often is unavailable to students until they become employed. Introducing students to such experiences earlier can foster the development of these abilities.

X4_1. The real effort expended equals that of the theoretical one.
X4_2. The evaluation is consistent with the rules presented at the beginning of the course.
X4_3. The evaluation processes measure knowledge correctly as well as competencies.
X4_4. The evaluation components are coherent with the activities scheduled.
X4_5. I learned concepts, tools and techniques that are new and valuable to me.
X4_6. I learned to do things related to this matter that are useful and completely new to me.
X4_7. Overall, I support the evaluation system for this course.

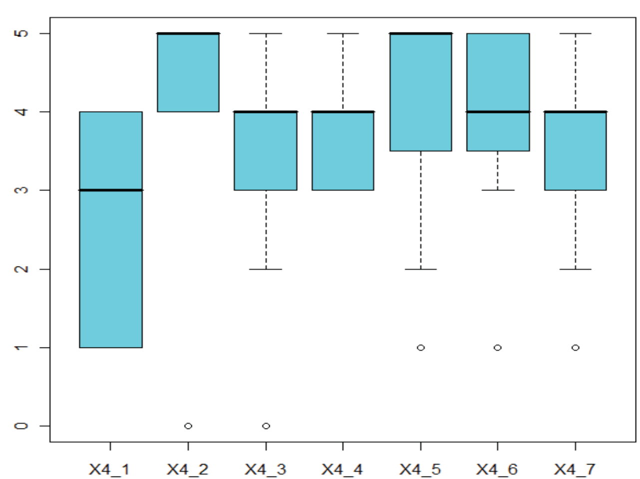

Figure 3. Boxplot of learning opportunities

A comparison of inexperienced and experienced students also reveals aspects that require special management. Young students are much more reluctant to make practical assumptions that are not directly related to specific mathematical formulas. In contrast, the students who possess previous work experience make assumptions naturally. However, because of their individualism and empowerment, they require a much more experienced manager. Management that has strong leadership attributes is clearly required here to avoid providing various fragmented solutions to the customer, instead of one well-focused approach.

When the project manager fulfills his role, the solutions provided are more practical than those generated by inexperienced students. This analysis supports the relevance of work experience as an additional skill provider to formal knowledge with an impact on student performance. When the project manager doesn't fulfill his role, the risk of project failure is much higher than in the other case. This is also a lesson that was learned, demonstrating its relevance for the profession of project manager in real life.

The perception of both the students and teachers is that the learning approach tested was valuable and more productive than lecture-oriented approaches, despite the fact that it required greater effort than the classical method, in which most of the effort is spent as examinations approach.

This does not mean that the learning approach presented is in an optimal state because, according to the lessons learned, there are improvements to consider making to the lessons. The easiest improvement to implement would be to design some 'gates' for practical projects to help project managers to have individual goals to refer to concerning the progress desired.

One issue is the number of class students as some scheduled tasks are class size-dependent, including the blended learning tools.

These tools were rated as very relevant for both students and teachers as they make possible direct feedback from an individual's reading, as well as an individual's work. Also, they make non-synchronous work possible by means of common repositories, forums with email alerts and many other useful tools.

The experience could be adapted to other courses by changing the project area to one that aligns with the subject of the course concerned. Our immediate plan is to complete the experiment by comparing the work of the teams. The following step will be to study and measure how technical information about project management improves the execution of practical work. In order to accomplish this, specific objective measurement looking for effectiveness of this learning approach will be established. Also, scalability characteristics will be analysed by running the approach with nearly two hundred students integrated into sixteen different teams.

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Integrating Teams In Multidisciplinary Project Based Learning in Mechanical Engineering

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Abstract—**Mechanical/Industrial Engineering students at Higher Technical School of Industrial Engineering (ETSII) of Technical University of Madrid (UPM) receive an in-depth knowledge of mechanical design and manufacturing processes, but the increasing interaction with other engineering branches, induces the need to integrate concepts which allow students to make an integral design of new products, and thereby facilitate their subsequent integration into multidisciplinary engineering teams in industry.**

Complex engineering projects are usually carried out by the assimilation of different work teams, which could even be located geographically distant. Collaborative Web environments are proven to be ideal knowledge repositories, as it has seen in Academia and in Industry. The work here presented reproduces the organization of actual engineering projects, and brings it into the classroom.

This new way of developing Project Work documentation and discussion has helped students become self-directed learners who internalize specific topics from different subjects, programmes and courses with their own interests, and has been considered as an easy alternative to promote active learning, not only in this area but in other courses.

Project were launched in the engineering disciplines, each offering possibilities for the application of specific skills in the following courses: TEC -Manufacturing Technology-, CAD -Computer Aided Design-, SIM -Simulation in Mechanical Engineering-, and FAB -Fabrication / Manufacturing. TEC and SIM are applied in the Mechanical Engineering programme at ETSII, while FAB is part of the Industrial Engineering programme; finally CAD is voluntarily employed by students in different semesters and programmes. The new approach is oriented towards inducing collaboration within multidisciplinary teams.

This paper describes the experience of collaboration among students and teachers in order to develop multidisciplinary projects, and to reproduce as closely as possible, the team's integration into a company environment. A new methodology based on student interaction and content development in a Wiki environment has been developed. The collaborative server has allowed creating an "out-of-the-classroom" active discussion forum for students of different teams /topics, and to compile an important "project work" portfolio. This experience has been very satisfactory for students and teachers, who have participated with enthusiasm due to the exit of the well-distributed work and the easiness of use of the selected platform (Wiki). The quality of the developed projects has been dramatically improved due to the integration of the results provided by the different teams.

Keywords: Project Based Learning; Active Learning; Collaborative Work; Multidisciplinary Approach; Wiki Environment, Teaching Mechanical Engineering

I. Introduction

Mechanical/Industrial Engineering students at Higher Technical School of Industrial Engineering (ETSII) of Technical University of Madrid (UPM) receive an in-depth knowledge of mechanical design and manufacturing processes. The increasing importance of the electronics, hydraulics, pneumatics, etc. in this field induces the need to integrate multidisciplinary knowledge which will allow students to make a whole design of new products and thereby facilitate their subsequent assimilation into multidisciplinary engineering teams in industry.

The use of project-based learning that allows students to participate in complex projects was already reported quite a while ago. Examples of these experiences can be found in many areas, with a positive evaluation in the case of learning in engineering.

The main objective of this experience has been to design a set of projects to be developed by students, mainly in the area of automated engineering, where students have to work in cooperative groups of three and have to integrate their results with groups from three other different subjects. They used a Wiki server to share and prepare their work content. This server integrates the information available from all projects with the following advantages:

- "Out-of-the-classroom" discussion with the ensuing improvements in students' ability to conceptualise.
- A simple, homogeneous compilation of the documents contributed by students.
- The chance to improve knowledge in other areas of interest.

The use of collaborative WEB environments is now commonplace in university education [1] [2]. The new technology platforms such as Blogs, Wikis and RSS feeds are proving to be invaluable educational tools that satisfy the constructivist theories of active learning [3]. Some experiences are specifically oriented towards teaching in Engineering and many are suited to collaborative work [4][5].

Some authors emphasise creating case study portfolios to promote an efficient understanding of concepts by students [6]. These case studies give rise to different ideas and have been proven to be an ideal mechanism for stimulating conceptualisation.

The Wikis are an excellent environment for a knowledge repositories and many experiences have been developed in teaching [7] [8] and in industry [9].

The use of Wikis helps improve students' reasoning abilities and their interaction with Wikis, and can be done outside the classroom as previous experiences have shown [10], where work on a collaborative project is considered as a way for students to add to the knowledge acquired in theory classes.

II. PROJECT DEVELOPMENT

A. *Team organization*

This educational initiative has been applied in four topics directly affecting 110 students working in different subjects and another 44 students that set the work for the students in each group of independent students.

The wordings for these works were launched with their particularities for the different subjects comprising the experience:

- TEC: Manufacturing Technology. (Code 1463).
- CAD: Computer Aided Design. (Code 9004).
- SIM: Simulation in Mechanical Engineering. (Code 1461).
- FAB: Manufacturing. (Code 1684).

TEC and SIM are topics in the Mechanical Engineering curriculum at the ETSII and are taught in the sixth semester while FAB is part of the Industrial Engineering programme taught in the eighth semester, and finally CAD is a free choice subject. Students in these subjects have carried out application projects for years but with this new experience, they are moving towards collaboration between disciplinary teams in different subjects. A collection of manufacturing cells was proposed to be worked on from four different points of view, to study and analyze them, and subsequently four different team approaches would be embraced to be solved in each of the previously mentioned topics.

This project carried out by students is shown in Figure 1 from four points of view reflected by the typical topics of these subjects and, therefore the tasks to be solved are seen from four different approaches.

Groups of three students were selected for each project and topic except for CAD which were two-student teams. Initially the teacher and students set the boundaries of the project for each topic.

The teachers involved in this experience organised fortnightly coordination meetings in order to coordinate course content timetables. Figure 2 shows an example of a problem in handling an automatic packaging machine. The difficulty of the projects proposed is uniform, but the work sequence and other specifications must be set in advance for each topic.

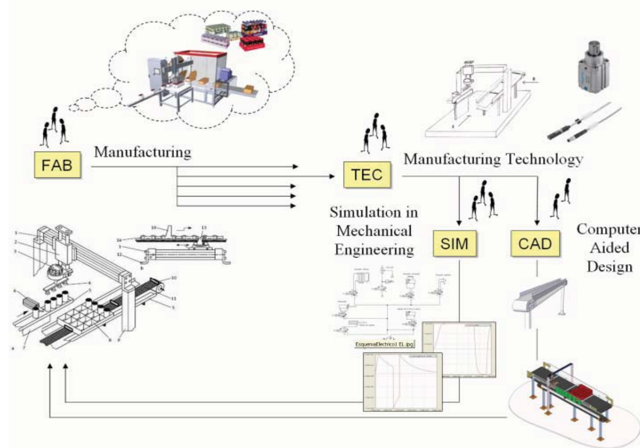


Figure 1. Four different teams for each manufacturing cell project.

Ten different types of manufacturing cells were designed. The cells proposed are shown in Table I:

TABLE I. MANUFACTURING CELLS

Manufacturing cells	Acronym
Parts manipulation in injection molding process	DPPMI
Machine to make pipe ending bezels	MBFT
Panel manipulation	MP
Can packing machine	EL
Saw cutting unit	US
Quality control for trays	CCB
Glass sheets positioning	PC
Tubular parts feeder	APT
On demand storage feeding unit	AM
Adhesive application station	AA

TABLE II. WORK EXPECTED FOR EACH TEAM:

Teams	Function
FAB	Manufacturing process selection and planning
TEC	Process simulation in the manufacturing cell
SIM	Design, drawing and drafting for the manufacturing cell
CAD	Design, drawing and drafting for the manufacturing cell

B. Publication and development on the collaborative Web

When each team has defined their particular area of contribution, the collaborative Web begins its task, which is basically to integrate all the information from student contributions and show it to the other teams with the purpose of enhancing the overall quality of the results produced.

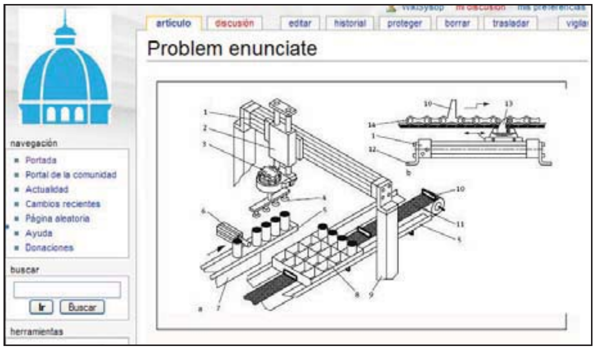


Figure 2. An example of the type of project proposed. A can packaging machine (EL). The project was provided by the teacher.

To facilitate an exchange of experiences and communication among the team members assigned to developing each manufacturing cell for the different topics. Once a week they could use a collaborative classroom, where the 11 members from the different topics that had designed the manufacturing cell could exchange information face-to-face or solve problems that could not be sufficiently clarified by the Wiki.

Figure 3 shows one of these inter-group exchange classes in which the different teachers from the four topics involved answered any query and realized how the projects were progressing.

Figure 3. Team coordination meetings

In the FAB and TEC topics, the rest of the students worked to provide the main groups with information (Figure 4).

Manufacturing Cell (11 students)			
CAD Group (2 students)	MEC Group (3 students)	FAB Group (3 students)	SIM Group (3 students)
	Subgroup 1 to n	Subgroup 1 to n	

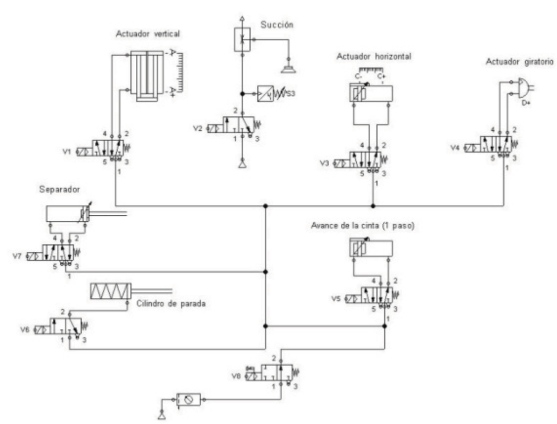
Figure 4. Organization of the work groups

Figure 5. A preview of the wiki space for a work team; solution provided by one of the CAD teams about the can packing machine shown in figure 2.

Figure 5 shows a solution to the formulation of the problem set in Figure 2 by the CAD team, chosen for publication in the so named WikiFab collaborative Web (acronym of Wiki Fabrication) [11]. MediaWiki 1.11 was chosen for its simplicity of configuration, its popularity (it is used in Wikipedia) and its powerful Wiki functionality.

In this Wiki, students must perfect the different issues set in the project. The discussion page contains everything related to working sequence and the starting conditions, such as the parts references provided by the manufacturers or the various design changes (Figure 6). All this information is discussed not only by the team members themselves but they also can receive comments from the members of other teams.

It is important to mention that the recommended format for offering solutions is a graphic format. This forces students to train their synthesis skills to express the objectives of their models through schematic outlines or diagrams. In another of the machinery stations, Figures 6 and 7 show different approaches to the proposed project model and the solution adopted respectively. The discussion page currently allows interacting with the teacher and other team members to be able to discuss the details of the proposed model.



(a)

(b)

Figure 6. Different approaches to the project. (a) from the Manufacturing Technology subject TEC, (b) from the Manufacturing subject FAB.

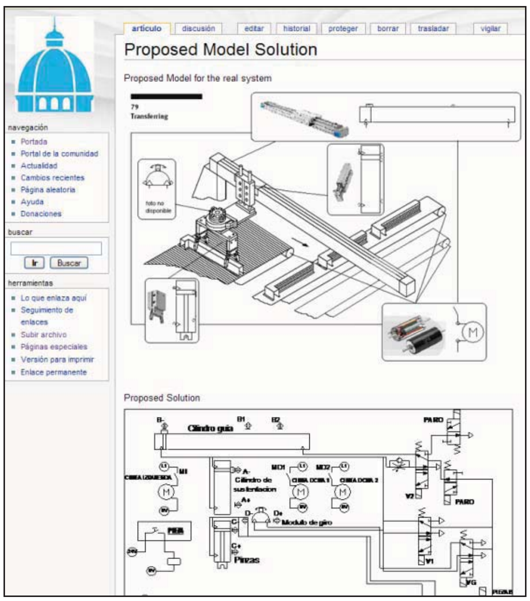


Figure 7. Solution for the proposed model

III. RESULTS

Every week, the students involved had to fill in a set of reports to evaluate team progress, interaction with other members and the problems they found in the assimilation of the project. These evaluation reports were prepared using Google Docs forms. Teachers use these reports to detect bad team behaviours and delays in the teamwork process.

Two general checks were also made midterm and at the end of the semester to evaluate satisfaction and the evolution of competencies.

A. Influence on the marks of the subjects involved

Figure 8 shows the average mark attained for TEC, CAD, SIM and FAB by students who took part in this experience (Project Based Learning PBL) and those who did not. It can be seen that there is difference between the two groups in the different topics as well as in the progress of the competencies developed.

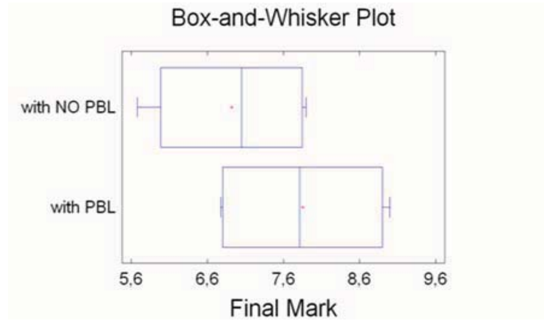


Figure 8. Comparison between students that follows the PBL method

B. Follow-up checks

Two checks were made midterm and at the end of the semester to evaluate student satisfaction. The questions contained in the survey were scored on a scale of 0 (zero) to 5 (completely in agreement). The questions were as follows (Table III):

TABLE III. CHECK QUESTIONS

Question Number	Question
Q1	Select your subject.
Q2	The 'multidisciplinary' work method is preferable to classic 'teacher-delivered lectures'
Q3	I think my work assessment method is correct
Q4	The teacher recognises the extra effort required to do work outside the classroom
Q5	The effort made to take part in the project is worthwhile. It would be a mistake not to take part in this experience.
Q6	Would you recommend it to a friend?
Q7	Score the WikiFab enviroment
Q8	I have improved my ability to work in multidisciplinary teams
Q9	I can estimate work execution times more accurately
Q10	I am more precise in the work I do
Q11	I have improved my ability to work with different teams by having to exchange information .
Q12	I have more leadership ability

Q6 has no numeric answer, the responses could be 'Yes', 'No', or 'I don't know'.

C. Statistical analysis

The results of these surveys were analysed statistically, obtaining the findings described below. 154 students answered the surveys: 23 students were enrolled in the CAD subject, 53 students applied in FAB topic, 28 students were working in SIM and 50 students in FAB.

Figure 9 reflects how at the end of the semester the scores for satisfaction showed a perceived improvement in competencies, although not in a major way, since from the start of the programme students perceive a positive improvement in their competencies. The multidisciplinary method used compared to the traditional one is scored favourably (Q2).

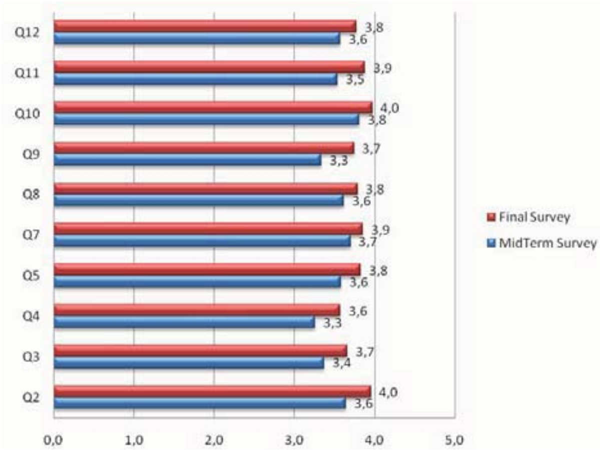


Figure 9. Mean of the questions results for Q2 to Q12

It can also be seen that there are no important deviations in the sample taken (Figure 10):

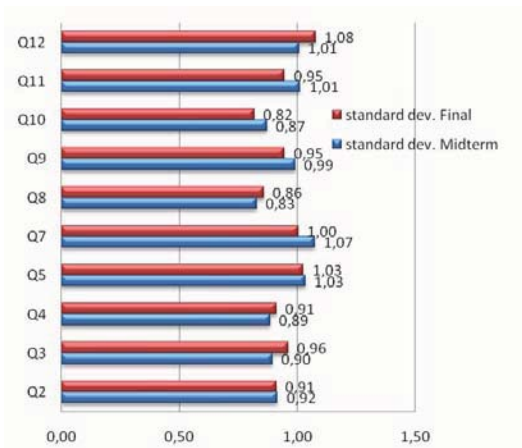


Figure 10. Standard deviations for Q2 to Q12 results

Regarding question Q6 "Would you recommend it to a friend?" the following results were obtained. It can be seen how in midterm students are doubtful of the benefits of the programme. However, at the end they are satisfied (Figure 11).

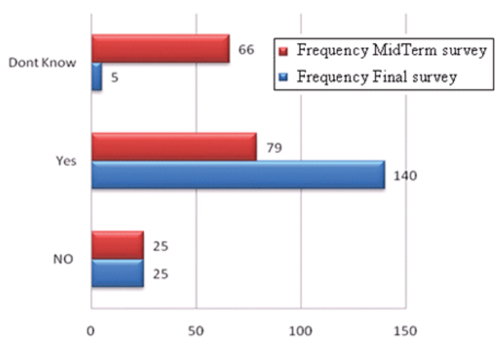


Figure 11. Histogram corresponding to Q6 results.

Chi-square test were made and 'P-value = 0' (< 0,1) so we can reject the hypothesis that rows and columns are independent at the 99% confidence level.

Therefore, the observed value of Q6 (fig. 11) in the midterm survey is related to its value for its subject.

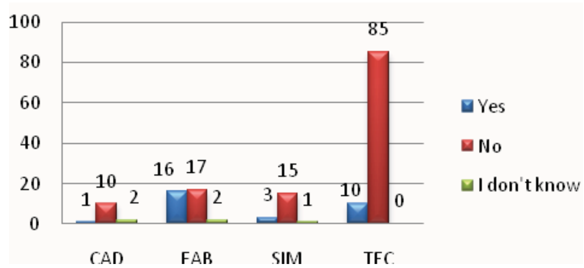


Figure 12. Q6 results in the midterm survey

This Q6 question was studied in the final survey again obtaining a clear correlation with the topic's students belong. Performing the Chi-square test, Since the P-value = 0,0056 is less than 0.01, we may reject the hypothesis that rows and columns are independent at the 99% confidence level. Therefore, the observed value of Q6 in the final survey case is related to its value for the applied subject.

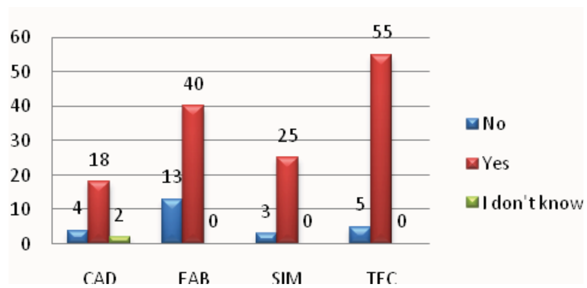


Figure 13. Q6 results in the final survey

D. *Analysis by subject*

An ANOVA analysis was made of the different student opinions regarding the topic they were studying. These findings refer to the final survey conducted in the semester.

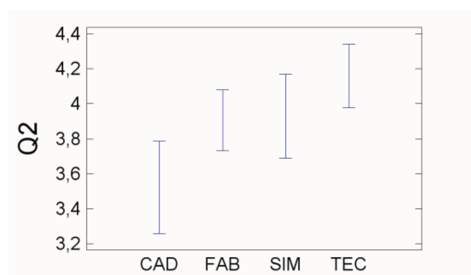


Figure 14. ANOVA(means and 95,0 Percent LSD Intervals) of Q2 results

The response to Q2 shows discrepancies between the CAD and TEC groups (Figure 14). We use the Student t-test to know if the groups are or not are homogeneous.

The responses to Q3 and Q4 show a homogeneous distribution for all groups. The response to Q5 shows discrepancies between the FAB and TEC groups. The FAB students do not positively score the extra effort required compared to multidisciplinary work.

On the other hand, these students are from the Industrial Organization specialisation and are not purely Mechanical Engineers (Figure 15).

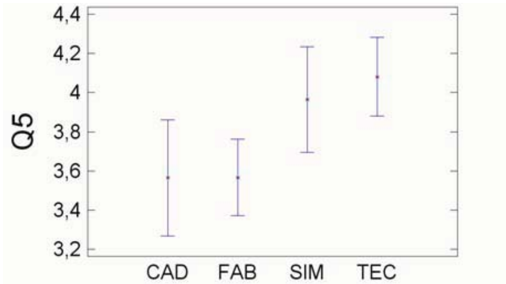


Figure 15. ANOVA (means and 95,0 Percent LSD Intervals) of Q5 results

However, question Q7 did show more disparate performance as Figure 16 shows. The SIM and TEC students score it very positively, which was not the case with the other groups.

The SIM students found the Wiki to be a very useful environment for developing their work and the TEC group, moreover, was driven by a teacher who was highly enthusiastic about its use and deployment.

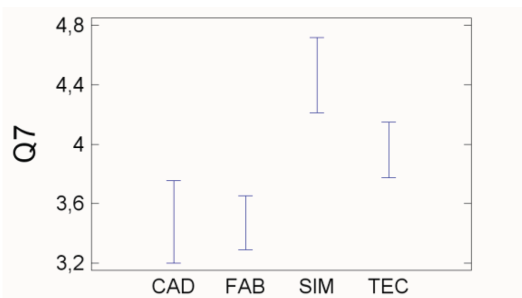


Figure 16. ANOVA (means and 95,0 Percent LSD Intervals) of Q7 results

The CAD students did not perceive any improvement in their work in multidisciplinary teams (Q8) compared to the other groups (Figure 17).

The TEC and FAB groups considered they had improved their time calculation estimates for jobs (Q9) better than the other teams (Figure 18).

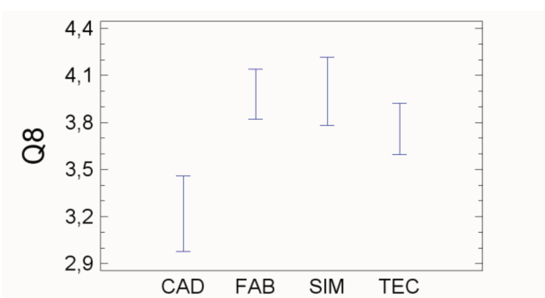


Figure 17. ANOVA (means and 95,0 Percent LSD Intervals) of Q8 results

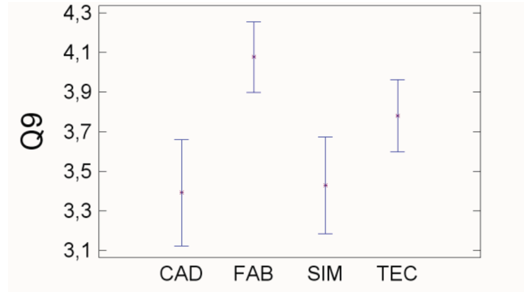


Figure 18. ANOVA (means and 95,0 Percent LSD Intervals) of Q9 results

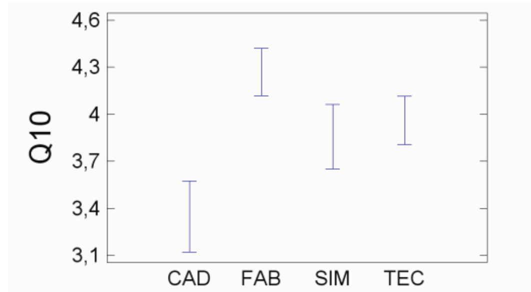


Figure 19. ANOVA (means and 95,0 Percent LSD Interv.) of Q10 results

Regarding Q11, the ability to exchange information was compared to other teams. All the means were above 3.5 points with the FAB teams giving the highest scores (Figure 20).

The FAB teams best score leadership ability (Q12). The CAD teams do not consider they have improved their leadership abilities (Figure 21).

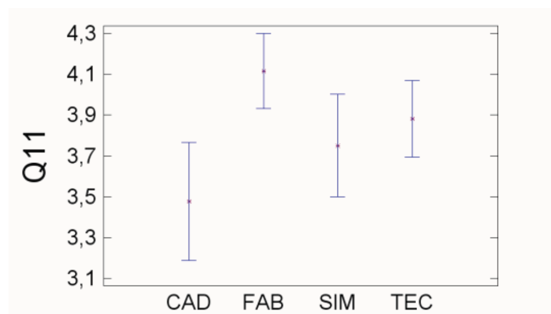


Figure 20. ANOVA (means and 95,0 Percent LSD Interv.) of Q11 results

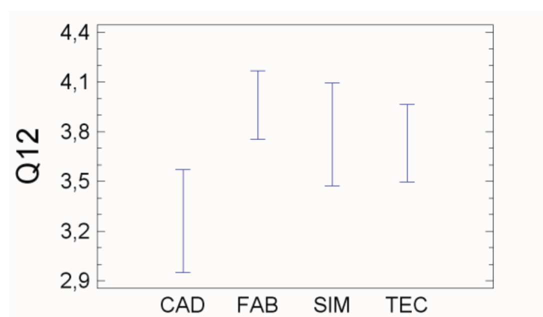


Figure 21. ANOVA (means and 95,0 Percent LSD Interv.) of Q12.results

IV. CONCLUSIONS

We have presented an experience for a large number of students involved in four topics from two different specialisations related to the Mechanical Engineering course of the Industrial Engineering degree. The use of a collaborative Web environment has made it possible for students to work in multidisciplinary teams. Students analyse, reason, discuss and decide on the solutions that their companions keep suggesting until completion of the project. This project has enabled students to approach a problem from four different points of view and mould them to the opinions of the other contributions from different subjects.

This new way of carrying out the project in this paper and its subsequent discussion has been very enthusiastically received by the student body and the teaching staff who consider it a simple alternative for promoting collaborative tasks between different groups.

The Web structure will let a major set of automated manufacturing case studies to be collected in a homogeneous format that may well become a virtual reference space in this area.

ACKNOWLEDGEMENTS

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A Project-Based Learning Approach to Teaching Power Electronics

Difficulties in the application of Project-Based Learning in a subject of Switching-Mode Power Supplies

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***Abstract*— This paper presents the introduction of Problem-Based learning (PBL) in a power electronics subject at the University of Oviedo (SPAIN) by means of two practical projects: the design and construction of a Switching-Mode Power Supply (SMPS) prototype and the static study of a dc-dc converter topology. The objective of this change in the traditional methodology of the Power Electronics course is to foster the application of the knowledge acquired by students in theory classes. PBL is known to be a motivating, problem-centered teaching method that brings the real professional world closer to the student. For this reason, the lecturers considered PBL to be the most suitable methodology to obtain the desired results. The underlying methodology, task planning and assessment of these projects will be presented. Furthermore, the influence of the introduction of PBL in practical sessions versus the traditional teaching method will be discussed. Finally, the lecturers' reflections and conclusions regarding the application of PBL in this subject over the last two years will be presented.**

Keywords- Proyect-Based Learning (PBL), significant knowledge, power electronics, switching mode power supply, practical sessions.

I. Introduction

It is well known that electrical engineers are recognized for their contributions to technology and for their improvements to global conditions. This is due to the fact that their main skill is the application of mathematics and scientific knowledge to the real world. However, traditional practical classes in Electrical Engineering curricula may obviate this fact because they are seen by students as a mere requirement without any interest in the real world. Therefore, the main skill involved in electrical engineering (the transfer of acquired scientific knowledge to society) is not enhanced because students do not see the real application of the work carried out in practical sessions.

On the other hand, the overall current aim of the Bologna Process is to create a European Higher Education Area (EHEA) based on international cooperation and academic exchange that is attractive to European students and staff from other parts of the world [1]. This means that all the undergraduate and masters degrees in Europe must have the same structure. In Spain, this change in the structure of university degrees is being employed to change the traditional methodology used to teach. Taskplanning and methods must now focus on student learning. Therefore, we must use active teaching methodologies to obtain significant student learning as opposed to mechanical learning. Significant learning goes beyond just understand-and-remember and even beyond application learning. In other words, students build their own knowledge on the foundations of their prior experience and know-how [2].

Taking into account the aforementioned motivations, a team of lecturers at the University of Oviedo (Spain) introduced the Project-Based Learning (PBL) methodology in a subject called "Sistemas Electrónicos de Alimentación" (Power Supply Systems) in the academic year 2007/2008. This subject, part of the final course of the Telecommunications Engineering degree, deals with Switching-Mode Power Supply (SMPS) and power supplies systems. The objective of this experience is to foster the application of the knowledge acquired by students in theory classes. In other words, the goal is to put into practice all the concepts regarding power electronics acquired during the entire course. For this reason, the lecturers proposed two projects to students: the design and construction of a SMPS prototype (boost converter) and the static study of a dc-dc converter topology.

First, this paper presents the methodology and task planning for the two projects. Second, the results of the application of PBL over the last two years will be discussed. Then, the lecturers in the subject present the main difficulties of the application of PBL after two years of experience. Finally, proposals aimed at improving the application of PBL for the current course and the conclusions will be presented.

II. Objectives of our experience. Why PBL?

Bearing in mind the main goal and the motivation underlying this experience, the lecturers in the subject gave them the form of more specific objectives. They were contextualized within the subject's requirements and were formulated as competencies which the student must have acquired by the end of the course:

1. To provide students with the fundamental concepts of SMPS and to prepare them for advanced study and research in this area: basic topologies, power supplies systems, passive components (inductor, transformer and capacitor), semiconductors, etc.
2. To learn how to search for, classify and analyze technical information about power electronics equipment and component datasheets and to be able to identify suitable sources of information about switching power supplies..
3. To provide laboratory experience to supplement theory in switching power supplies and to promote the application of theoretical concepts.
4. To provide students with the ability to propose solutions to problems and to enhance the critical reasoning needed to choose the appropriate solution in accordance with specific criteria.
5. To enhance other transversal competencies within the Telecommunications Engineering degree course such as the ability to write technical reports properly and to develop the ability to speak in public.

Having defined the objectives of the subject, the lecturing team had to select the most suitable methodology to obtain these goals. We chose PBL due to the fact that this methodology prompts students to encounter the core concepts and principles of a discipline while managing a specific task (project), thereby enabling the application of acquired knowledge [3,4]. Furthermore, PBL goes beyond the relationship between knowledge and thinking, helping students to both "know" and "do". In fact, this methodology focuses on “doing something” and “learning on the way”. The main characteristics of PBL from the point of view of student learning can be summarized as follows:

1. PBL is student-centered and focuses on their main competencies. Students design the process for reaching a solution. Therefore, they focus the task around their main concerns and skills. In fact, the end product is a reflection of themselves. For this reason, students have no problem spending a lot of time implementing their projects.
2. PBL helps students to solve problems by themselves: self-management, project management and critical knowledge are enhanced. As they program their own work, PBL thus permits frequent feedback and consistent opportunities for students to learn from experience. Self-assessment takes place continuously during project development.
3. PBL recognizes the capacity of students to do important work and their need to be taken seriously by placing them at the core of the learning process. It engages and motivates bored or indifferent students. PBL is designed to establish a student’s commitment to the task to be done.

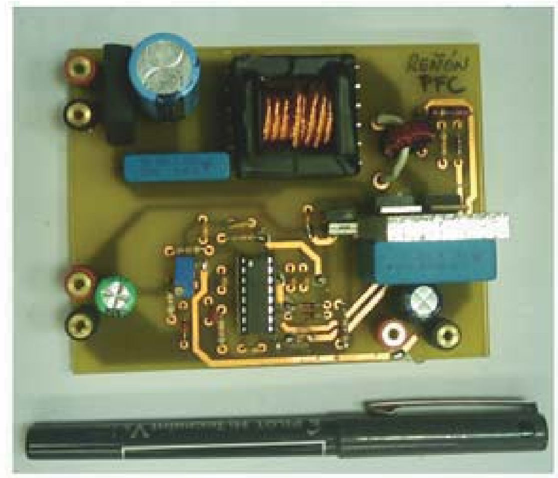

Figure 1. Switching-Mode Power Supply (SMPS) prototype made by a student.

4. PBL creates positive communication and collaborative relationships with lecturers and other students. PBL can help the lecturer to create a high-performing classroom in which the group (the lecturer plus the students) forms a powerful learning community focused on achievement, surpassing oneself and contributing to the community.
5. PBL includes the development of high-order knowledge and high-order competencies. Thus, PBL seeks significant learning.

Within a multidisciplinary educational context (i.e., Electrical Engineering, Telecommunication Engineering, etc.), PBL appears as one of the most interesting instructional strategies. In brief, the PBL strategy aims to engage students in authentic real-world tasks and open-ended projects that can increase motivation for most of them. For this reason, in recent years some authors have used PBL in their Electrical Engineering degree classes [5-7], in particular in their practical sessions [8-9].

III. METHODOLOGY APPLIED IN PRACTICAL AND PROBLEM-SOLVING SESSIONS

Two projects were introduced in the practical and problem-solving sessions of a SMPS subject forming part of the University of Oviedo Telecommunications Engineering curriculum.

A. Design and construction of a Switching-Mode Power Supply (SMPS)

An experimental prototype of a SMPS was designed and built in the practical sessions (7 sessions of two hours and 1 session of 1 hour) of the subject by each student. The assessment of this project focused on the student-learning process that becomes practical know-how. The end product (Fig. 1) was only evaluated as a part of the process. Therefore,

Figure 2. Laboratory student desk and devices to develop the practical sessions.

the application of the knowledge obtained in the theory classes is the goal of this project and the goal of the assessment.

At the beginning of the course, each student was assigned a laboratory desk with all the devices and instrumentation needed to develop the project. In the first session, students familiarized themselves with all the material. The rest of the practical sessions were divided into design sessions and building sessions. In the former, students had to design a part of the SMPS. In latter, students had to build this part. At the beginning of all these sessions, the lecturer briefly explained the concepts of the work to be done. All the lecturer's explanations have to be brief and to the point and have to drive student learning. After that, the students developed their part of the project with the lecturer acting as a mere facilitator, redirecting all the technical problems that arose during the session. At this point, the interaction of the students among themselves and with the lecturer is very fruitful because positive communication and a collaborative relationship is created. Moreover, as the sessions progressed, the lecturer raised challenging issues or questions that led students to in-depth exploration of authentic, important topics related to this part of the project. Student reflection regarding these issues was very important. All the concepts proposed at the beginning and all the questions raised during the class were carefully planned in each session. In the final session, students experimentally presented their SMPS prototype.

The lecturing team took special care with respect to the student-learning process. For this reason, tutorial classes were proposed to students when deficiencies in their knowledge appeared. Sometimes it was necessary to review and clear up concepts presented in classes.

B. Static study of a dc-dc converter topology

The second project undertaken by students was the static study of a dc-dc converter topology. The objective of this project only focused on obtaining theoretical knowledge.

The theoretical model to develop this static study was explained during theory classes with basic dc-dc converter topologies. Mid-course, a different project was proposed to each student. It is the lecturing team's belief that students have sufficient knowledge at this point to tackle a high-order problem. This project was the static study of a non-basic converter topology. In this case, the student role was authentic PBL: students were engaged problem-solvers, identifying the root problem and the conditions needed to obtain a good solution. They were also pursuing meaning and understanding, as well as becoming self-directed learners.

During the rest of the course, the student developed this static study in parallel with theory sessions in which the lecturer established similarities between the problems which had been solved during the course and the project to be developed. Yet again, a specific time for reflection was proposed by the lecturing team. For this reason, all the solved problems presented in the problem-solving classes were carefully planned after the project was launched. Finally, the project was presented as a MATLAB spreadsheet. In this project, tutorial classes were also fundamental.

IV. ASSESSMENT OF TWO PROJECTS

A. Design and construction of a Switching-Mode Power Supply (SMPS)

The assessment of this project was planned differently from a traditional one. The lecturing team wanted to assess the learning process instead of the end product: in this case, a SMPS. The lecturer responsible for the practical sessions drew up a report on each student in every practical session. Thus, continuous assessment was carried out. The lecturing team thought that this project was particularly well suited to be included in a continuous assessment scheme in order to evaluate the main competency that students have to acquire: namely, application of the knowledge acquired in theory classes. Also, students presented a report with a thorough explanation of the tasks carried out during practical sessions. An experimental presentation and verification of the prototype was also conducted with the idea of promoting oral expression and public presentation in the final session.

The practical session reports drawn up by the lecturer, the final report on the SMPS design and the experimental presentation of the prototype were used by the lecturers to assess this project. This project counted for 30% of the final mark for the subject.

B. Static study of a dc-dc converter topology

The students presented a MATLAB spreadsheet (Fig. 3) with the solved static study of the proposed topology at the end of the course. They explained their solution to the lecturers and answered their questions with the idea of assessing the design process they had implemented. In this case, the goals of this assessment were to evaluate the ability to propose solutions to problems and to enhance critical reasoning to choose the appropriate solution. The fostering of oral expression and presenting in public were additional competencies likewise assessed in the presentation and defense of this project.

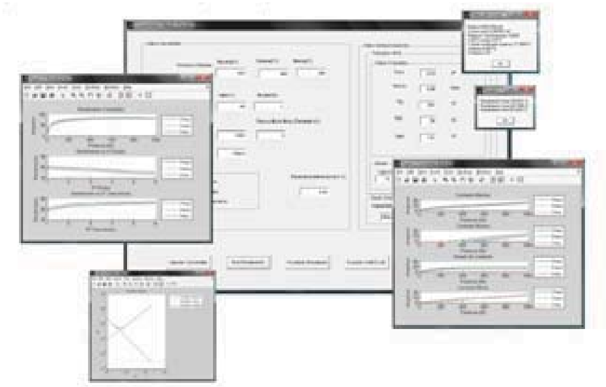

Figure 3. Example of a spreadsheat programed in MATLAB.

The project was assessed by means of a report on the presentation of the spreadsheet drawn up by the lecturer. This project counted for 20% of the final mark for the subject.

At the same time, a traditional exam was sat to complete the assessment of the subject, counting for 50% of the final mark.

V. Student Surveys

At the end of the course, the lecturing team conducted a survey to ask students about the PBL methodology introduced in this subject. The results of this survey are shown in Fig.4. The main topics in this survey focused on the development of the main student competencies that the lecturing team wished to improve via this experience, the improvement of other skills and a general assessment of the subject.

As can be seen, students positively rate the improvement in their ability to solve problems, to apply the know-how acquired in theory classes and in their ability to make decisions. In fact, the opinion of the students can be summarized in a student comment that was common in all surveys:*" I enjoyed working in a power electronics laboratory developing the design of a converter very much. It is very interesting to solve real problems and to face challenging activities like this project"*

Other skills that students improved were reflected in the survey as positive issues: namely, the ability to search for and to assimilate information on their own, oral expression and writing technical reports.

Finally, the experience of this subject was also positively rated. As can be seen in Fig. 4, the students appreciated the planning time and the assessment of the subject. They were also very satisfied with the work carried out in the two projects forming part of the subject.

VI. Lecturers' reflections after two years. The dificulties of PBL aplication.

It seems logical that the assessment of this experience (the application of PBL) does not depend solely on student opinion. For this reason, the lecturing team established periodic interviews and meetings with students throughout the course. The results of this experience were thus deduced taking into

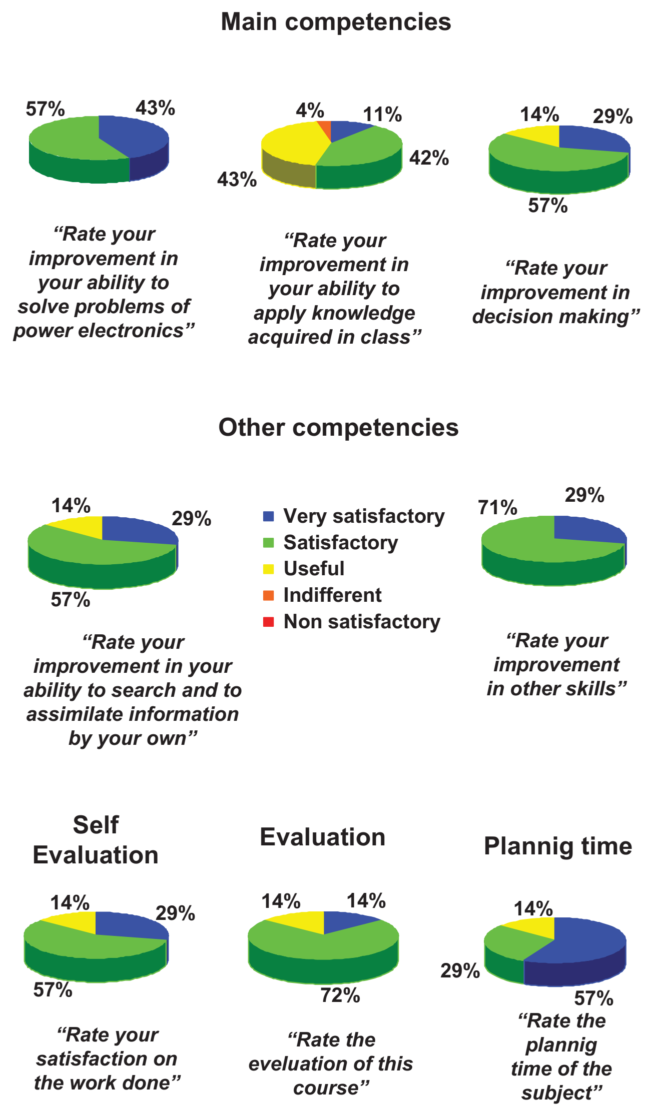

Figure 4. Student survey scores

account the surveys, meetings, interviews and final marks obtained in the subject. These results made us reflect on the application of the PBL as a new learning methodology. We conclude that the application of the PBL is neither straightforward nor easy. Including PBL in a subject curriculum presents a number of difficulties. We summarize our main reflections in what follows:

A. Student exam results were worse than their projects. Are we evaluating the learning process appropriately?

The results of both projects were very satisfactory from the technical point of view. All the students designed and built the SMPS prototype and obtained a certain benefit from the process, while the proposed static study was correctly developed. However, the results of the theory exam were worse

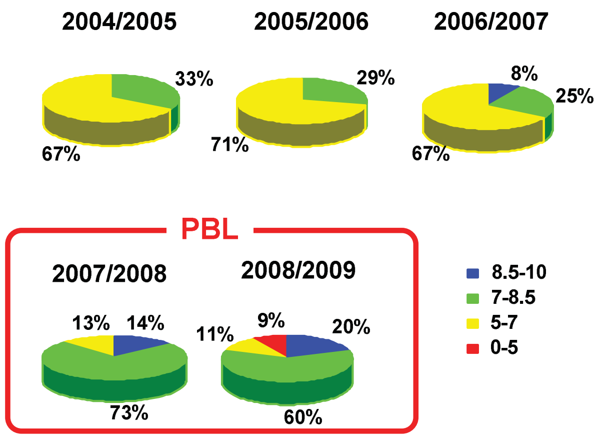

Figure 5. Marks obtained in the subject.

than expected. There were some mistakes in basic concepts developed in theory classes. We found that students apply acquired knowledge in practical projects as a "small recipes" in order to solve specific problems in project execution. Furthermore, they use a "blind" trial-and-error system to tackle the problems that arise in the projects. In both cases, although students solve their difficulties during the execution of the project, they do not acquire an overall view of the subject and significant learning is not achieved. These results lead us to think that we did not suitably assess the student learning process. We made a mistake: we assessed the results of both projects (the SMPS prototype and the MATLAB spreadsheet) but did not assess the student learning process. This fact is reflected in the final marks obtained in the subject. The marks for the last two years are better than the previous years when PBL had not been introduced in the subject. Figure 5 shows the marks obtained by the students in the last five years. Students fail if they get less than 5 marks out of 10. These marks are grouped in four intervals, which represent the qualification that is given to the student. As can be seen in Fig. 5, although most students passed the subject, the percentage of those who obtained the highest marks has increased significantly with the introduction of PBL in the subject. These results are due to the fact that the qualifications of the projects of the last two years are better than those of the practical sessions in the subject in the years 2004/2005, 2005/2006 and 2006/2007. However, the exam marks are equal to or worse than non PBL courses.

In order to improve the assessment of the student-learning process during the practical sessions, we intend to include rubrics in the present course (2009/2010). These rubrics will replace the report drawn up by the lecturer on each student in every practical session. These rubrics have been designed to carefully assess the main competencies to enhance: to promote the application of theoretical concepts and to provide the student with an ability to propose solutions to problems and to enhance critical reasoning. Also, this assessment methodology (the rubrics) will be applied to qualify the final report of the SMPS design, the MATLAB spreadsheet, the experimental presentation of the SMPS prototype and the defense of the static study. In this case, we wish to assess other competencies: the ability to write technical reports properly and the improvement in speaking in public.

B. *Is the exam the greatest enemy of PBL?*

Traditionally, PBL plus exam is a bad combination in a traditional course where the exam possesses the greatest weighting with respect to the final mark [10]. To implant PBL in a course requires a new perspective of the role of the exam.

According to our experience, the exams done by students are a continuous source of frustration to lecturers because the marks obtained by former are worse than the expectations of the latter. This is due to the fact that student projects, developed during the course, are generally very good. This fact may suggest that the subject should be only assessed by means of projects. From our point of view, however, all the efforts made during the course cannot centered around PBL. In fact, we only apply PBL in our subject to enhance a number of student competencies principally the application of technical and scientific knowledge acquired in theory classes. For this reason, we use theory classes to provide students with a broad view of the main concepts in the subject and to foster in them prior reflection before practical sessions. Therefore, we are convinced that theory classes are fundamental and we wish to highlight this conviction. As a consequence of this, the exam is necessary. Perhaps we have to rethink the role of the exam, bringing it more in line with the projects developed in the subject or planning the projects more in accordance with the exam. Another possibility is to plan an exam that ensures the basic concepts of the subject that students must have acquired.

C. *We all have to accept that mistakes are necessary to learn*

Student motivation was not constant throughout the two projects. The lecturing team expected student motivation and dedication to be very high when tackling real projects. This appreciation was however mistaken. The students were highly motivated during the first sessions. However, they have to master high-order reasoning as projects of this kind evolve. At this point, the students were found wanting in terms of their knowledge and the application of basic concepts acquired in theory classes. As a consequence of this, student motivation declined. Moreover, lecturer despair likewise increased. This situation (drop in motivation) was repeated during the project.

After two years of applying PBL in our subject, we must bear in mind that this is a normal situation in PBL and does not constitute a drawback. Lecturers and students have to accept that errors are necessary in order to learn and to apply acquired knowledge. It is very important for lecturers to make students aware of this fact in order to motivate them when problems arise. The motivation of both students and lecturers as the project evolves is like a "roller coaster". In some situations, the passengers (lecturers and students) might wish to get off the roller coaster. However, we have to keep up our motivation and that of our students in order to achieve the ultimate goal of PBL: significant learning.

D. The time spent on PBL. A real change for lecturers and students

First, lecturers need to be aware of the dedication that PBL requires. Monitoring, driving and implementing the work undertaken by students require time. The time spent on these activities is greater than the time spent on traditional learning methods. This is a new scenario that lecturers have to assume.

On the other hand, students have to plan their time during project implementation. It is normal for students to encounter problems in managing their own time, as they traditionally work on tasks planned by the lecturer. In each practical session, students only have to solve one planned problem. If students do not complete their tasks then they can redo this practical session at the end of the course because each practical session is self-contained. The problem to solve now is the project. The project presents a number of problems during its implementation and now the problems that arise presented are different for each student. The presented problems depend on the strategy used by the student to tackle the project. This situation seriously upsets student planning. Common student comments in practical sessions are: "it is too much work to develop in practical sessions", "we have to work a lot before practical sessions", etc. However, all students carried out the work planned by the lecturer in practical and problem-solving sessions and presented their assignments on time. Furthermore, surveys revealed that the time spent by students to prepare and develop both projects was less than the time scheduled by lecturers. These reflections show that students are not comfortable managing their own time.

E. The application of PBL requires aninvestment in resources and facilities

If a new active methodology is applied instead of traditional methods, then the facilities to develop this new methodology also have to change. Therefore a inversion in this methodologies has to be done [11].

The lecturing team is aware that this experience can be carried out because the number of students enrolled in our subject is low. "Sistemas Electrónicos de Alimentación" is an optional subject in the 5th year of the Telecommunications Engineering degree with an average of 12 students per course. For this reason, practical sessions of 6 students can be planned in our research laboratories to implement the SMPS project. However, this current year we have 30 students enrolled in our subject and so had to equip a new laboratory to develop the SMPS project. In this case, practical sessions of 10 students have been planned with two lecturers supervising the group in each session. As can be appreciated, PBL requires an investment in resources and facilities.

VII. CONCLUSIONS

Our experience in the application of PBL in the subject: "Sistemas Electrónicos de Alimentación" has been extremely positive for us and for students. However, we conclude that the introduction of PBL in our subject is upsetting for both parties. It implies difficulties which we are still solving after two years of applying PBL: facilities, assessment of the learning process, etc. We hope that the results obtained each year serve to improve the application of this methodology.

On the other hand, this methodology is appropriate to achieve the objectives proposed at the beginning of this experience. Students are motivated with this new scenario because they tackle and solve real problems in their projects. We have to benefit from this new atmosphere to guide students to significant learning. It is a great opportunity!

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Session 04C Area 2: Virtual Worlds for Academic, Organizational, Life-long Learning and training - Virtual environs

GE3D: a virtual campus for a technology-enhanced learning

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Dynamic Virtual Environment for multiple Physics Experiments in Higher Education

Bailey, Philip; Dos-Santos, Fabio Ricardo; Guetl, Christian; Harward, Judson

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Learning Dynamics and Control in a Virtual World

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University of Sydney (Australia)

Virtual University as a Role Playing Game

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GE3D: a virtual campus for technology-enhanced learning

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***Abstract*—There are many learning management systems all over the world. But these conventional E-learning platforms aim at students who are used to work on their own. Our students are young (19 years old – 22 years old), and in their first year at the university. Following extensive interviews with our students, we have designed GE3D, an E-learning platform, according to their expectations and our criteria. In this paper, we describe the students' demands, resulting from the interviews. Then, we present our virtual campus. Even if our platform uses some elements coming from the 3D games world, it is always a pedagogical tool. Using this technology, we developed a 3D representation of the real world. We also propose a process of a lecture on the Programmable Logic Controllers (PLC's) in this new universe. GE3D is a multi-users tool, with a synchronous technology, an intuitive interface for end-users and an embedded Intelligent Tutoring System to support learners.**

Keywords-component: virtual campus, Technology-Enhanced Learning, learning systems platforms, engineering education, Intelligent Tutoring System, Multi Agent System .

I. INTRODUCTION

There are so many learning management systems (LMS) all over the world, that to choose one is difficult. Among them, Moodle is the one mostly used [1]. Five years ago, our university decided to implement it for all syllabi. Until now, it is a statement of fact that this tool is at best underused or at worst unused. There are many reasons explaining this lack of interest. The most important are the learner's loneliness, the lack of ergonomics and the way it is used: like a bookcase or a set of compartments for documents. This platform must be an exchange and communication area, supporting knowledge acquisition by links established between end-users, belonging to the same interest community. The subject taught and the students' profiles are decisive factors in the choice of the shape and functionalities given by the LMS. In order to explore the expectations of the students, their way of life, their uses of Internet and their computer equipment, an assessment of their needs was conducted. Following the results obtained and according to many studies on the value added by three dimensional environments (3D) in e-learning [2-6], we have designed GE3D, a virtual campus with the SCOL technology [7].

Finally, we will focus on the lack of the individual tracking and the communication with the learner, which generate a risk of disinterest and eventually desertion. For Carr [8], the desertion rate is over 10 to 20% when compared to face-to-face classroom learning. How can we prevent this risk in the knowledge acquisition process? The intelligent tutoring system (ITS) embedded in GE3D, based on a multi-agent system (MAS), provides solutions. It allows a more accurate interactivity, keeping the learner in touch.

II. SURVEYING THE NEEDS OF THE STUDENTS

The students were surveyed for their expectations and criteria for a learning system platform [9]. They are young undergraduates (19 years old – 22 years old). There are more boys than girls preparing this technological diploma (Department of Electrical Power and Industrial Computing). 220 students were surveyed for the report.

The students are playing 3D games (90%), by network (55%). The majority of students have personal access to internet (68%), with a high speed connection (50%). This connection is often used: every day (37%), from one to several times per week (33%). The time spent for each connection is: 1 hour (26%), from 1 to 3 hours (29%), and more than 3 hours (17%). They use the connection at first for entertainment then for communication and finally for work. They communicate with an instant messenger software (e.g. yahoo messenger) (62%) and by e-mail (74%).

After the general questions, we asked them for the qualities of a "good web site". The first quality is quickness, followed by the content, and then the clarity. A lot of our students (69%) know the web site of the university, but a large number (72%) does not know the Moodle platform and more do not use it (85%). For our students, a LMS must be in addition to the traditional courses (85%), instead of a unique and complete solution (9%). For knowledge acquisitions, they consider facing the teacher as essential (62%). For them, IT isolates people rather than getting them closer, and improves communications rather than deteriorating them. In their expectations of an ideal numerical campus, our students want first to get their time schedule, then complements of the traditional courses, then more exercises and the old exams with the solutions. They want a "hot-line" with the teachers and a communication area with them, a simple but quick web site, and finally they want to access simultaneously with other students on the site.

Following this survey, a first 3D virtual campus prototype was presented to the students, with the topic concerning Programmable Logic Controllers (PLC's). We can summarize the results of the second interview by the following:

- They want a serious 3D environment for classrooms, without anything likely to disturb them.

- For the practical area, they want a room with an industrial look. They want to see the PLC's with an operative part. They want to interact with the system by pressing buttons and observing what happens. In this area, they want to realize something by themselves.

- They do not want a sophisticated avatar for their own representation in the 3D. They just want a simple shape textured with their photo on it. This way, they can recognize who is here at the same time. They think that a human shaped avatar does not give additional information in this virtual world.

- The audio component is essential, but reserved for the teacher. During a session, students put questions by text in the chat module and the professor answers by audio to all the students.

Now, taking into account all the students' recommendations, we will present the final version of a virtual campus for students.

III. GE3D: A SOLUTION

The choice of a virtual campus rather than a traditional LMS (e.g. Moodle) is obvious for the students in the Department of Electrical Power and Industrial Computing. They are experts in playing 3D games on network. According to their expectations and our criteria, we have designed GE3D, with the SCOL technology. The choice of that technology was driven by the specifications: Web3D technology, open source to allow our own developments, platform independent, with client-server architecture.

A. *Description of the 3D world*

In the first area (Fig. 1), we can find in the 3D part a mail box to send e-mail, a board for the time tables, a board for the assessment marks, a board for the system help, a clock to be on time, a door to access other areas.

Figure 1. Entrance of the virtual campus

Figure 2. Amphitheatre with an avatar

In the lower part of the window, we can find on the left the numbers and the names of the connected people, several functions for login, for choosing a representative photo for the avatar, for a private chat between two users and a general map of the site. Under the blue scrolling banner announcing the last news, we can find a public chat available for all the users.

Fig. 2 shows the amphitheatre where synchronous presentations can be done. On the right is a large screen on which videos, slides or drawings can be sent by the teacher. Learners take place on the seats in front of the screen. Only the teacher can use the audio line. In the lower part of the window, we can see the public chat where students ask questions to the teacher.

The next room (Fig. 3) shows the industrial part of the site. Here is a SIEMENS PLC, the same used by our students in our department. A simple actuator is presented here by a cylinder and its Sequential Function Chart (SFC) programme. This 3D environment allows the users to undertake activities in a synchronous way. For example, when one student activates the SFC, the rod of the cylinder moves according to its evolution cycle. At the same time, all the connected users can see synchronously the cylinder movements and the SFC evolutions. Other simple exercises are available in the same room. If a student can complete with success all the exercises, then he can access videos of five more sophisticated industrial processes made with a commercial software [10-11]. In addition to the videos, the student gets the specifications of each industrial process. When they have prepared their own programs of the process, they come back to reality in the real PLC's room where they can test them. As always, if they meet some difficulties, they can get help from peers, teacher or intelligent tutoring system (ITS) through the chat.

Having described the resources available in GE3D, we will now explain how to fit them in a pedagogical scenario.

B. *Pedagogical scenario*

A typical structure of a course on PLC's could be the following:

Figure 3. Industrial area in GE3D

1. An appointment is given to all the students at the amphitheatre.
2. Before entering, the students download lecture notes with gaps they have to fill during the lecture.
3. During the presentation, the lecturer can use the screen to upload notes or slides. He can also use a white board and a microphone for the audio. Meanwhile the students complete the lecture notes and put questions through public chat if needed. The teacher answers the questions by audio for all the students.
4. After the lecture, the students answer an online multiple choice question test. In case of success, they can access the industrial part of GE3D. If they fail the test, they replay the recorded lecture.
5. In the Industrial room, the tutor demonstrates how to use the equipments and explains what he is expecting from the learners. He leaves the students working by themselves but remains available to answer the questions.
6. When the students complete all the given exercises, they can download specifications and videos of a complex industrial process simulator.
7. After programming the process the students can join the teacher to validate their program on real PLC's.

The interviews further revealed that although students can collaborate with each other in GE3D they demand more contact and communication with teachers. In this regard, with the aim of helping tutors and students, we have developed an intelligent tutoring system (ITS) in GE3D.

C. Intelligent Tutoring System to prevent students from giving up

The three main parts of the Intelligent Tutoring System (ITS) are (Fig. 4):

- Four Human-Computer Interfaces (HCI) in blue.

- Three knowledge parts in green.

- A four layers hierarchic multiagent system (MAS) in red, developed with Jade [12].

The MAS inside this ITS is based on previous works with the hypothesis that some parts of the MAS are generic; i.e.

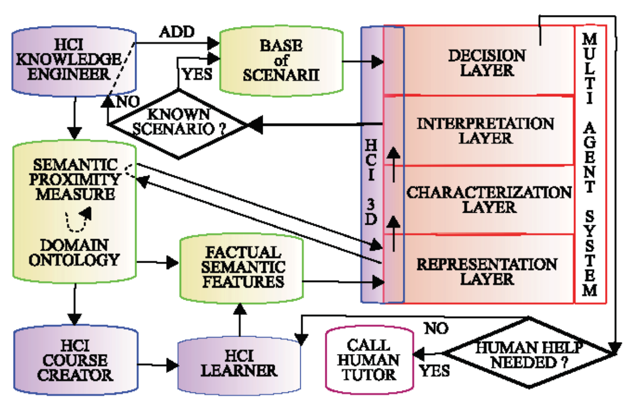

Figure 4. Architecture of the Intelligent Tutoring System

knowing the domain ontology and therefore the structure of factual semantic features (FSF), which are domain specific, the three lower layers of the MAS (representation, characterization and interpretation) are independent of the domain. Previous works were applied to crisis management in an oil plant [13] and emergency logistics [14] with this MAS.

The representation layer receives data from the learner as FSFs. Each agent of the representation layer (factual agent: FA) keeps this atomic datum. Then the given FA computes internal indicators. Those indicators reflect the importance of the FSF in the whole representation. At any time, all FAs represent a snapshot of the situation. From a dynamic point of view, variations of these internal indicators represent the evolution of the situation. The ability to take into account this dynamic point of view is the reason why we choose MAS paradigm [15].

The structures of FSFs are extracted from the domain ontology [16]. The knowledge engineer defines a semantic proximity measure used to compare FSFs included into FAs. Related FAs according to this measure belong to the same semantic group.

The characterization layer clusters the FAs of the representation layer. This partition is a synthetic description of the current situation.

Using this synthetic description, the interpretation layer looks for similar scenarios in the database. If not recorded, the knowledge engineer can add this situation. Depending on the scenario, decision layer chooses either calling a human tutor or a non-human tutor or adapting the learner's course.

IV. CONCLUSION

In 2010, the way our students use IT is not the same compared with the 90's. Addicted to their mobiles they send SMSs all day long. Competing for growing their Facebook relationship and experts in playing video games, they do prefer to stay at home facing their laptop instead of experimenting the real world with its real residents.

Building new systems for distance learning, we have to take into account these behavioral evolutions. Thus, we have designed GE3D. In addition to the above reasons we can notice that real actuators are too expensive. Furthermore, we cannot imagine beginners in PLC's training with a real complex industrial process. These good reasons justify our stand to use virtual equipments in GE3D world.

Unlike video games, where the efficiency of 3D renderings and physics engines counterbalance the weakness of the scenarios, the content must remain more important than the packaging. The pedagogical scenario described in this paper and implemented in GE3D can be easily modified. Its architecture can combine lectures, learning through projects (i.e. collaborative learning), learning with and from the peers (i.e. cooperative learning) and learning by problem solving.

Students prefer to learn by doing, on their own initiative and without being under the teacher's pressure. Nevertheless, they demand immediate help and attention from a tutor. The ITS implemented in GE3D is the facilitator for students and tutors to accomplish this.

Our next goal is to expand GE3D into a clustered Web server to increase the number of connected people and to raise the reactivity of the system.

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Dynamic Virtual Environment for Multiple Physics Experiments in Higher Education

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Abstract—**The transportation of a campus classroom and/or laboratory into a three dimensional virtual representation has changed remote learning, specially in engineering education. Our first collaborative virtual environment, a proof of concept, provides full functionality of one physics experiment, though there are still some performance issues to be resolved.**

The next step for integrating TEALsim and iLabs in Sun's Project Wonderland is porting our system from Wonderland's version 0.4 to 0.5. Our goal is a system redesign in order to support adding flexibility to multiple physics simulations. The performance improvements in Wonderland 0.5 will allow a large number of avatars in our future scenario, where they will be able to run even more physics experiments, through a new 3D user interface.

Keywords-collaborative immersive environment; virtual worlds; Project Wonderland; iLabs; TEALsim; physics experiments, remote labs, visualization.

I. INTRODUCTION

In the past few years, especially due to the increasing availability of faster and robust hardware and software, 3D environments have become common technology. Virtual laboratories, scientific visualizations, and some collaborative work approaches are just some of the successful fields of 3D graphics applications.

One essential term is Virtual Environment (VE), which is a computer generated spatial environment, where the stimulation of diverse human senses gives the user a feeling of being immersed. Immersion means how deep the user is emotionally involved within a specific virtual environment [1].

Nowadays, a great research challenge for educational technology professionals is to build technology that not just supports the learning process, but also connect students and educators in a way so they can easily cooperate, even when both parties are geographically spread.

Our first collaborative virtual environment provides full functionality of one physics experiment. This environment results from the integration of internet-accessible physics experiments (iLabs) combined with the TEALsim 3D simulation toolkit in Project Wonderland [2]. Students and educators, represented as avatars, within this environment can remotely control experiment equipment, visualize physics phenomena generated by the experiment and discuss results. This environment was developed following the Technology Enabled Active Learning (TEAL) classroom idea to support social interactions, encourage student's active learning and interest, in an environment that fosters conceptual change [3].

This study explores the process of conversion of the TEALsim simulation package to the rendering engine jMonkeyEngine (JME), which is the graphics engine used in Project Wonderland version 0.5. Additionally, we have built a Wonderland cell class that can dynamically load TEAL simulations into Wonderland by the end of the research project. This will provide a collaborative environment similar to the current 0.4 version, but using the new graphics engine.

Furthermore, we implemented an automatic generation of the simulation's controls in the Wonderland environment either as buttons, sliders and other control elements within the 3D space or as elements in the Heads Up Display. These controls will provide the standard Java event handling model.

Therefore avatars have the ability to directly interact with TEALsim elements, including moving elements and activating sensors. Changes in the environment would be updated in real-time.

Finally, based on the latest research, this paper outlines the future research directions and challenges to overcome.

Figure 1. Close-up view of the 'Force on a Dipole' Experiment in Wonderland 0.4

This research has been partially supported by the Austrian Marshall Plan Foundation.

II. Related Projects

A. iLabs

An iLab stands for an internet-accessible experiment that can be reachable remotely at any time over the internet. Compared to conventional laboratories, iLabs are available 24-7 and are easily shared. Since they provide access to unique remote resources, they are less expensive and complex than conventional labs. Users can access these online laboratories from around the world through a single standard administrative interface. In engineering education, iLabs enrich the scope of experiments students have available to them in the course of their academic careers [4].

B. TEALSim

TEALSim, the TEAL simulation system is designed as a framework for authoring, presenting and controlling simulations in a variety of domains. It was developed by the Technology Enabled Active Learning (TEAL) Project at Massachusetts Institute of Technology (MIT) [3]. Among others, the objectives of this project are to increase student's conceptual and analytical understanding of the nature and dynamics of electromagnetic fields and phenomena, and also foster student's visualization skills.

Figure 2 illustrates an example of how TEALSim is very useful in electromagnetism helping students to visualize and process phenomena. During the Force on a Dipole experiment, TEALsim enables students to see the invisible magnetic field lines, which of course are not visible in real settings. This visualization behaves according to changes in simulation input values made by students, giving them a better understanding of electromagnetic fields. Such visualizations allow students to make abstract ideas concrete. [3]

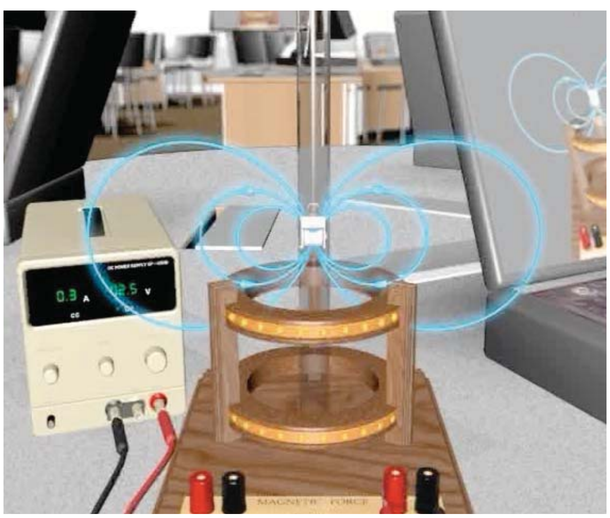

Figure 2. The *TeachSpin*™ apparatus from the Magnetostatics Session.

C. Project Wonderland

Project Wonderland is a toolkit for building 3D virtual worlds, which has been developed by Sun Microsystems Laboratories [5]. Based fully on 100% open source Java technology, Wonderland is extensible so developers and graphic artists can extend its functionalities to create new collaborative 3D virtual worlds. Wonderland also supports a high level of communication via highly immersive audio and enables desktop application sharing, among other features.

In the new redesigned version 0.5 of Wonderland, JMonkey Engine is one of the supported rendering engines. In the Wonderland project, jME helps us to specify 3D objects in a scene [5]. This concerns an object's size, appearance and how they are related to each other. Not just computer graphics operations such as lighting and texture can be done through jME, but also complex techniques like particle systems.

MTGame is a Multi-Threaded Game engine build on top of the jMonkey Engine scene graph [6]. Its main purpose is 3D graphics content processing and rendering. MTGame extends the capabilities of jME offering a fully parallel processing model and a fully featured rendering system, which supports all major rendering techniques. Besides that, three plug-able systems are included: picking and collision, physics and an input system for some input devices. So basically, MTGame is a library for scene graph management and concurrency management.

Animations and other changes, which happen in wonderland scene graph over time, are managed by MTGame. Developers can use MTGame to animate various 3D Object attributes like position, color and lighting. Further information about MTGame will be explained in the next session.

Besides the gain in performance, another important feature of version 0.5 is the possibility of embedded Swing components for user interface development in world. By creating a swing-based interface, we can interact directly with the experiment instead of interacting with a LabVIEW application through VNC viewer.

D. jMonkeyEngine

Due to the lack of graphics engines written in Java, the open source jME was built. jME is an Application Programming Interface (API) dedicated for high performance scene graph based graphics [7]. The feature list of jME is extensive and includes embedded integration of Java Applets and SWT (Standard Widget Toolkit). jME Desktop System is responsible for the rendering of Swing components in jME scenes.

III. Collaborative Virtual Learning Environment

A. Overview

In CLVE students are represented as avatars, through them users communicate with each other, cooperate with other students or educators to solve common physics problems and experience physics experiments. This Virtual Environment extends the real studio physics classroom in many ways in order to support students understanding of physics concepts.

Students are able to interact with a remote experiment through a 2D LabVIEW front panel, for example changing experiment input parameters such as amplitude or frequency. This panel has been presented via the graphical sharing desktop system Virtual Networking Computer (VNC) until now since the LabVIEW application is running remotely in the computer wired to the experiment.

Synchronously, a 3D visualization of the simulation is generated from the input and output values in the experiment equipment. For instance, in the case of the Force on a Dipole Experiment, shown in Figure 1, students are able to compare the generated magnetic field lines with the real physical experiment, which is streamed in real time through a video camera. The network camera is provided by the iLab ServiceBroker.

Due to the lack of support of swing components in the 0.4 Version of Wonderland, a button was developed to start the virtual representation of the experiment and synchronize with the real hardware.

Furthermore, a whiteboard was added to the environment to use for post experiment discussion results. Textchat functionality is also provided. These tools give students the ability to interact with each other during the experiment and discuss results of their work, as it is in a real face-to-face collaboration.

B. TEALsim Architecture

TEALSim was designed according to the principles of the classic design pattern Model-View-Controller [8]. Many classes contribute to the functioning of each of these modules. While the simulation engine represents the Model, the user interface represents the Control. The viewer and renderer constitute the View. A simulation consists of the combination of these three modules with the collection of simulated objects and user interface components specific to the simulation. All simulation elements are JavaBeans and implement the TElement interface. Interfaces provide the basic functionality of the component, leaving the customization for its implementation.

A typical basic Electromagnetic simulation will include a simulation engine, a viewer, which by default is a Java3D viewer, UI elements and other objects being simulated. TSimulation interface describes the requirements for a complete simulation and brings all these components together.

Like any other object in the world, a simulation must implement the TElement interface, which describes the most basic functionality for objects in the world. Graphical elements, control objects and physical objects such as point charge implement this interface. A TSimulation class is responsible for the entire logic in a particular simulation. All the components in the simulation are managed by instances of a class that implements the TFramework interface. SimPlayer, is an implementation of TFramework, that loads a TSimulation object and presents it to the user either as a 3D desktop Java application or applet.

The third basic component is the SimEngine, the simulation engine. Basically, SimEngine performs three actions in a loop. First, it computes variables for the current time step, then updates simulation objects to reflect these new values. Completing the loop SimEngine informs the renderer of any visual changes to the simulation. This corresponds to the main application thread for a TEALsim simulation.

The Viewer represents the rendering engine, displaying 3D simulation elements on the screen. It also manages the user interaction with the rendered images. The interface TViewer defines rendering properties and tasks including camera controls, visual effects and also maintains a list of rendered elements. Each of the rendered elements is responsible for updating the portion of the scenegraph that represents its current position and state. These were considerations for the major architecture components in TEALSim.

C. Incorporating jME in TEALSim

Basically, three TEAL packages should be redesigned: scene graph, render, and geometries.

As Java3D API, jME is also a scene-graph based rendering engine. A scene graph organizes the data in a tree structure, normally spatially. In the case of the jME, scene graph nodes can be called either Nodes or Geometries, depending if we are considering an internal node or a leaf node.

Node's relevant information, like transforms have to be considered during the integration, because Java3D uses different utilities classes. Java3D fundamental types are slightly different than jME ones. These are Matrix,Vector and Quaternion.

Vector3f, Vector2f, Quaternions, Matrices are in jME float because LWJGL only supports float. That is, our double precision values handle the application side and are converted to float at the scene graph level.

Besides other minor changes, we start to substitute Java3D native geometries through jME fundamental shapes: box, cone, cylinder, sphere, tourus.

A factory method is used to facilitate the rendering engine migration. This method just instantiates an object. They are useful here because we can leave the concrete implementation of the conversion to the factory method. In the simulation we didn't know whether to create Java3D or jME instances. Instead we can use "render" and leave the instantiation of implementation to a factory method.

D. MTGame

Although jME is a robust scene graph based rendering engine, it does not provide everything necessary for rendering 3D real time simulation in Wonderland.

MT Game is a full performance Multi-Threaded Game engine, which fulfills this need and also takes advantage of new multicore client systems. In the API hierarchy, MT Game sits on top of the jMonkey engine scene graph and the Wonderland 3D client sits on the top of MT Game.

It extends the JME features by providing a fully parallel processing model and its rendering system supports all major rendering techniques. Besides that, it offers plugable systems including picking and collision resolution and an input system for processing not just mouse and keyboard events but also other devices. In addition, we use MT Game collada model loader to import our models into Wonderland.

MT Game is designed following a component model; this enables us to dynamically add new features to new models with almost no programmer intervention. All data will get into the system through a component. In this model our base object is called the Entity object, which is simply a container object for components that are responsible for the object visual and behavior. These components are created and managed by Managers. The Worldmanager object provides the access to all four Managers in the system: Render Manger, Input Manager, CollisionManager, and Physics.

E. User Interfrace Considerations

As relevant as the graphic engine are the interface controls. Several studies have shown that not well-planned navigation, complex user action models and annoying conclusions normally slow performance in the real world in the same manner that a 3D interface does [9].

This is the reason why we redesign the environment to integrate TEAL in Wonderland. Figure 3 shows the top view of our new environment. We always keep in mind to give the user in the virtual world fast situation awareness through effective overview of the simulation and we are always engaged to provide a meaningful feedback for user actions.

The controversy over 3D versus 2D interfaces is also present in Virtual Worlds. In scientific visualization we consider 3D as necessary to the number of tasks involving continuous variables, surfaces and volumes. However for other applications, a better strategy would be to explore variable relationships in two coordinated diagrams to discover trends, outliers or gaps.

Usability testing is more than essential for successful user interface design. So, for the development of a new prototype, which will integrate all the simulations from the TEAL project, we considered findings of our latest evaluation of the proof-of-concept [10]. In this study, we could compare how effective it is to be immersed in a 3D environment for educational purposes in traditional settings, specially related to understanding physics concepts.

Figure 3. The redesigned Collaborative Virtual Learning Environment in Wonderland integrated with TEAL Simulations

We start by grouping some high level objects together. 3D Simulation visualization, the interface controls and the camera were placed next to each other to provide the students an effective overview of the situation. This organization allows students a rapid visual search of any item. We have noticed that by doing so, students could accomplish their tasks with a reduced numbers of movements and clicks, thus reducing navigation complexity. Figure 4 illustrates this organization.

By the time of the development we were not sure about the implications of implementing either 2D HUD (Heads-up Display) or 3D interfaces in Wonderland cells. On one hand, a 2D version could boost performance and remove clutter to the plan view display. On the other hand, 3DUI can look similar to real world objects leading to a highly immersive environment. Our buttons can appear raised or depressed. Students normally enjoy these interfaces, according to the students preferences documented during the evaluation. In the cognitive domain we believe that students would easily recognize and memorize these objects because they improve spatial memory use [11].

Simulation elements in TEAL can communicate with any other element in the world since all objects must implement TElement interface. Its functionality includes support of Routes and ProperyChangeEvents. In such a manner, simulation objects can communicate with UI components. A property of a simulation object can be manipulated if we connect a UI element such as a slider. In our simulations, the Wonderland swing provided API is wired to the TEAL simulation objects.

Project Wonderland HUD consists of 2D windows, which appear above the 3D scene and they are not shared with other in-world users [5]. They can be either visible or iconified. We developed customs HUDComponents (HUDButtons) using the Java(™) Swing GUI toolkit to control and change some parameters of the simulation. To display the HUD component the user should select the simulation check box menu item. Since the Wonderland client core itself uses Swing to implement HUD, both are local GUI only and not shared among the users.

Parallel to this implementation, we use the Wonderland API to create 3D objects and make them react to user input events. This interface can be manipulated by multiple Wonderland users, instead of HUD, which can only be presented to one user. For the Force on a Dipole we developed a set of buttons to control the amplitude and frequency parameters and to turn on and off the simulation and the coil on the top corner. The great advantage of having 3D interfaces is that these buttons are shared among the other Wonderland clients. By organizing all the buttons next to the experiment, we avoid the unnecessary visual clutter caused by the larger VNC panel.

To define how big the 3D buttons are and how they look, we use the jME API. For the dynamic behavior of the 3D objects, such as the button animations we use MT Game processor objects. In order to display 3D interfaces we create a RenderComponent. Otherwise nothing could be displayed. Buttons can only react to user input when they are "pickable".

To make them pickable we need to attach to their nodes a collision component. Every time users press the button, the simulation opens a data socket to the lab view application. The TEALsim simulation engine receives the data through the socket channel and sends it back to update simulation objects to reflect these new values. As we mentioned earlier also part of the simulation engine rule is to inform the viewers rendering engine if there is any visual change necessary to be made. Having this 3D interface near the visualization minimizes the number of navigation steps for students to accomplish their

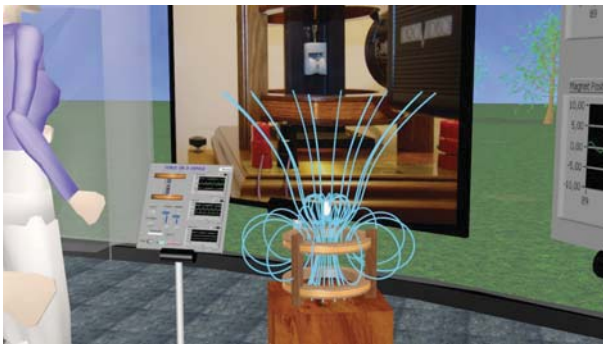

Figure 4. The redesigned Force on a Dipole Experiment in Wonderland

tasks in this environment. This also makes the environment more game-like, being dynamic and enjoyable for students and educators.

F. TEALSim & Wonderland Integration

The integration of TEALsim with Wonderland will not significantly change the process of creating simulations, but will provide Wonderland modules and cells that implement the TEAL framework. These modules will provide simulation engines that run within the Wonderland environment, render engines that execute in the Wonderland client, and manage the communication between the server and clients. In Wonderland a module is similar to a plug-in, just by including the TEALsim module and specifying the top level Java simulation class, it will be in your world.

As we mentioned, the TEALSim rendering engine is implemented as a Java3D based Viewer, which also handles the explicit rendering of the scene. Since Project Wonderland in its version 0.5 uses jME as its main rendering engine, we considered also a redesign of the TealSim 3D viewer. For many reasons, the viewer is tightly coupled to the SimEngine. Every time a simulation object has changed, the simulation engine has to inform the Viewer. Additionally, each of these elements has an associate visual representation, now as jME geometry. In the other way, when the user manipulates a visual object in the viewer, this should report back to the simulation.

IV. CURRENT STATUS AND FUTURE WORK

We plan to finish the TEALSim integration into Wonderland at the end of the Summer 2010. A stable version of this module should be running by April 2010. Depending on time and the level of integration of the game engine at this time, we will start to experiment with the NPC avatars or semi-autonomous tutors, making them intelligently react according to data stream.

Additionally, we are involved in the development of 3D interactive games, where students should be able to understand how magnetic forces and fields behave in nature.

V. CONCLUSION

This research investigates the learning benefit for students and educators by using avatars in virtual worlds for collaboration and educational undertakings. We strongly believe that CLVE plays an important role converging collaborative technologies and tools such as video, graphics and real time simulations.

Such a game like design, keeps students interest even though they are physically remote. Combined with peer cooperation, the real time visualization helps students fully understand the dynamics of electromagnetism [2]. More and more, students and educators are agreeing on the additional value of CLVE as an educational tool, fulfilling students and educators needs for an environment for remote communication and collaboration. Once the students see the same behavior at the same time, it is easier to cooperate on misunderstood concepts. Other than 2D applications, here users could explore our 3D space analyzing TEAL simulations from different locations in the room.

Moreover, the combination of a collaborative learning environment with internet-accessible iLabs is a less expensive solution for educators, because both are based in open source technology and sharing of resources. Some of the experiments and simulations could be very costly in traditional settings. Both are easy to use and are intuitive.

We are also planning to evaluate the different user interfaces approach considering student's cognitive process, relevant features and entertainment. Through such a study we can polish our design and generate new guidelines.

These are the first steps integrating TEAL Simulations in our collaborative virtual learning environment. We will continue to research ways CLVE can increase even more its pedagogical value fostering the learning process. Scientific collaboration may happen in the future primarily in Virtual Environments.

ACKNOWLEDGMENT

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Learning Dynamics and Control in a Virtual World

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Abstract— **Virtual worlds can support learning processes by providing visual aid that deals with the complexities of real life problems. Increasingly useful is the online use of virtual worlds and the associated technical and social interactivity. This paper describes the development of a virtual world in Second Life environment for dynamics and control learning, and outlines the use of this virtual world as a learning space in the elective course Process Systems Engineering. The outcomes based on lecturer's experience as well as on evidence from student feedback are reported and recommendations are made for the use of virtual worlds in Engineering education going forward.**

Keywords- virtual world; Second Life; learning; dynamics; control; education.

I. INTRODUCTION

The online classroom is becoming increasingly relevant in the modern connected world. For the purpose of experiential learning, i.e. laboratory and experimental based activities, many educationalists have developed online courseware targeted at experiential education. Some examples are given, for Chemistry laboratory education [1-3, 5], surgery [10], biology [10], physics [1, 2, 4], Chemical Engineering [6-8] mechanical engineering [6, 7, 9], and electrical engineering [6, 7]. The educational challenges are being met by clever utilization of information, communication and data management technologies. Most existing virtual labs take advantage of the simulation, connectivity and internet technologies but to date have the following limitations:

(1) they remain simple in nature with limited features,

(2) in almost all developments the laboratory is presented in a 2D interface,

(3) offer low usability levels, i.e. students cannot see facial expressions and get body language cues.

(4) offer low or no interactivity between the user and the virtual plant,

(5) offer low levels of scalability, i.e. limited number of students can use a particular virtual instrument at any one instant, and

(6) the simulations used are offline in many cases,

This has led to a high demand for online interactive multi-media environments that serve the goals of teaching and learning. Internet-based virtual worlds like 'Second Life' (SL) serve such a purpose very well. These environments allow students and teachers to interact with each other and with software agents through motional avatars, providing an advanced level of a social educational network service combined with general aspects of a metaverse, i.e. not limited to the physical classroom. Students can explore virtual classroom space, meet other students, socialize and participate in individual and group classroom activities. These virtual worlds have generally been well accepted by Internet users, indeed well embraced by the younger generations. Such immersive virtual spaces are flagged as highly advantageous for teaching and learning, particularly because virtual reality can help deal with the scope and complexity of real world problems where traditional classroom and laboratory settings create limitations. Educationalists are therefore adopting these to aid in delivering courses and improve aspects of their teaching and learning. This now has become an active field of research that looks into the way students learn in these environments and to measure the levels of improvement to the learning experience.

This paper (a) describes the development of a virtual world in SL for dynamics and control learning, (b) outlines the use of this virtual world as a learning space in the elective course Process Systems Engineering, (c) reports on the outcomes based on lecturer's experience as well as on evidence from student feedback and (d) makes recommendations for the use of virtual worlds in Engineering education going forward.

II. VIRTUAL WORLDS

A. *Virtual Worlds and Pedagogy*

There are several virtual world environments currently accessible to the public including Active Worlds [11], Second Life [12], There [13], Worlds.com [14] amongst others. A comprehensive list along with reviews of these virtual worlds can be found at [15]. While all these differ in their look and feel, they are all driven by avatars – i.e. by online manifestations of self designed to enhance interaction in virtual space [16]. While these environments have been overly used for social interaction and online gaming, educationalists have been quick to realize their value for teaching and learning, particularly because of the avatar interactions which emphasize a learner-centered education. At the same time there is the recognition of the enormous pedagogical challenges evolving due to the rise of virtual worlds. An important aim for the teacher is to initially understand learner behavior and how learning interactions occur in these up-and-coming environments.

The primary hypothesis from our pedagogical point of view is that "learning is enhanced using 3D virtual worlds". Successful implementation of a virtual laboratory is expected to enhance enormously the levels and ways experiential engineering and science learning takes place and will invite many other academics to assess their experiential teaching and learning strategies and to follow suit towards improving the effectiveness of their instruction with virtual avatar-based online classrooms and laboratories. The use of fully immersive 3D virtual spaces as environments for student interaction and learning are compatible with the following learning rationales:

- Constructivist learning: Learners participate in active problem solving with emphasis on the active role played by the learner to acquire new knowledge and concepts.
- Cooperative learning: Students learn most from their peers (and not from the teacher). Here students interact and cooperate with their peers on problem solving tasks.
- Situated learning: Learning is contextual and is embedded in a social and physical environment.
- Project-based learning: Real-life problems as learning tasks within a project setting (as described by the learning situation in Section III) enhance learning particularly when these are formed within multidisciplinary teams of students.

To begin to assess the primary hypothesis and to understand how students would benefit from learning in virtual worlds, our first objective is therefore to develop a virtual learning space to be inhabited by students learning process Dynamics and Control. The development of such a virtual classroom and associated laboratories is done in SL. This is described next.

B. Process Dynamics and Control and World Development

Arguably one of the driest and more challenging subjects to teach in the Chemical and Biomolecular Engineering curriculum is Process Dynamics and Control. The topics covered can be abstract and less motivating and typically result in students not making a connection between the fundamentals and physical implementation. Process Dynamics and Control is taught as a third year undergraduate module in the School of Chemical and Biomolecular Engineering and also inside the elective course Process Systems Engineering.

The principal aims of the Process Dynamics and Control module are to (a) understand the different dynamic behaviours exhibited by different processes in the Chemicals industry, and (b) to understand process control fundamentals to regulate the said processes. To this end, the virtual learning space was developed to provide a representation of a realistic process learning environment complete with several learning spaces (Figure 1). These include a lecture room shown in Figure 2 and collaboration/meeting rooms shown in Figure 3. A control room is built (Figure 4) to represent a realistic control room environment in a chemical manufacturing process. This is the brain centre of the chemical plant where operators monitor and control the process variables like process temperatures and flows via computer terminals. 3D visual representation of important chemical processes are built and distributed in four different laboratories positioned around the control room. Figure 5 shows a typical process (Mixing tank) in one of the four laboratories alongside an integrated slideshow. Figure 6 is from the distillation column control laboratory showing the visual capabilities possible inside the virtual world.

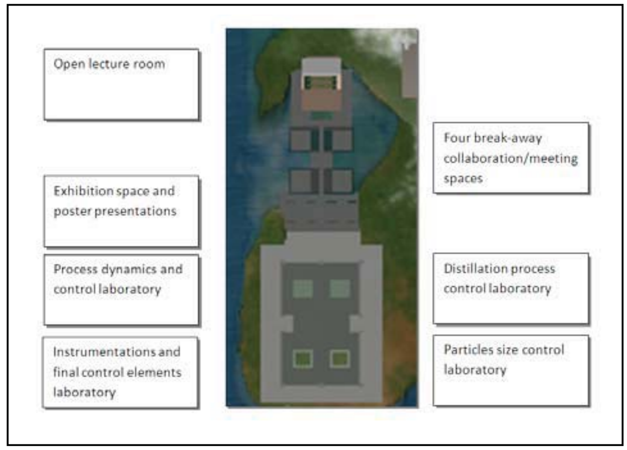

Figure 1. Aerial view of the virtual world developed for Process Dynamics and Control learning. Shown are the different learning areas including (from the top down) a lecture room, collaboration spaces, exhibition space, the four breakaway laboratories. Not visible is the control room positioned between the four laboratories and shown in Figure 2.

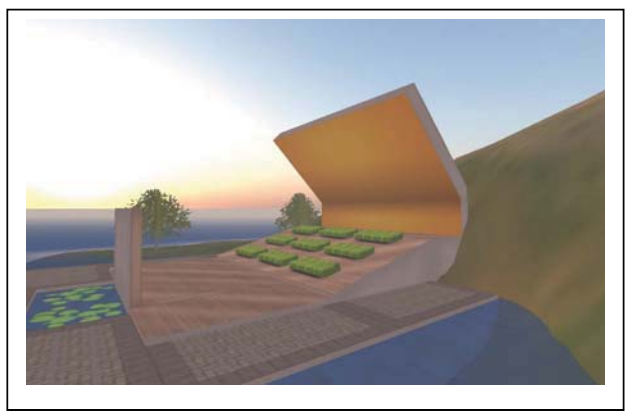

Figure 2. The virtual lecture room.

Figure 3. The virtual meeting/collaboration room.

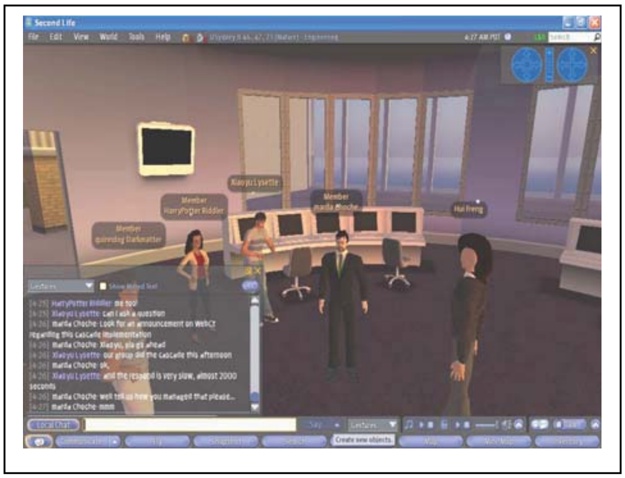

Figure 4. The virtual process control room. Student avatars can walk around, interacting with the lecturer (standing in the middle) and other students as well as with the control panels to operate virtual plants.

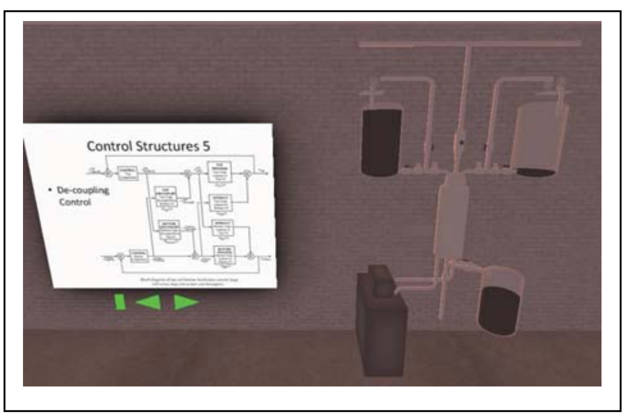

Figure 5. A virtual mixing tank (right) alongside an integrated slideshow (left).

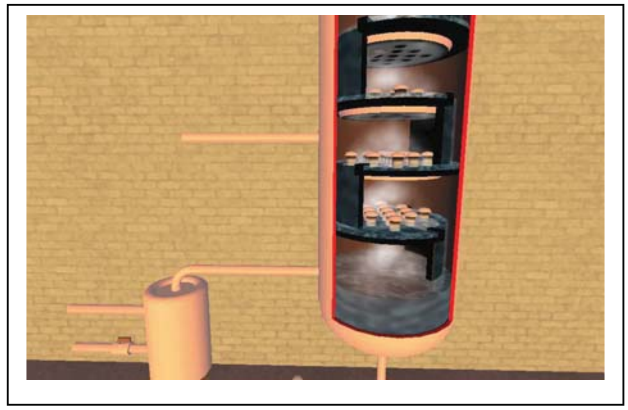

Figure 6. A virtual distillation column demonstrating visualisation capabilities inside the virtual world. Shown are the Column internals including the trays through which vapour rises contacting the liquid falling down on top of the trays.

III. LEARNING SITUATION

This section describes the use of the developed virtual world (presented in Section II) to support learning in the Process Systems Engineering unit of study delivered in the August Semester of 2009. The unit of study covered conventional as well as advanced control strategies in a project-based setting around the mixing system presented in [17] and shown in Figure 5. The project description as given to students is adapted from the "Temperature and Level Control in A Mixing Tank" problem in [18]. Students were required to work in groups to solve the project and prepare two reports – one mid-semester report and one final semester. Information on SL and the virtual space was distributed to the students early in the semester and it was left up to the students to register on the SL website and to create their avatars. While the use of SL in this unit of study was not made compulsory, it was continuously encouraged. Two SL consultation evening time slots were allocated during the week to provide students specific times for raising questions outside classroom hours. Student feedback was continuously gauged during consultation times while an end of semester questionnaire was used to obtain formal feedback.

IV. QUESTIONNAIRE AND STUDENT FEEDBACK

A. Questionnaire

The questionnaire was prepared aimed at gauging the extent of usage of SL in the unit of study as well as to understand what students thought of the environment. The survey questions are shown in Figure 7.

Questionnaire on using SL in Process Systems Engineering course.

Please provide some anonymous feedback on the use of SecondLife (SL) in the Unit of Study CHNG5001, in order to help us improve future course design. Thank you for taking the time to provide this feedback.

1. **How long have you spent in a country where English is a main language?** (please circle)
   - *a) Less than 2 years*
   - *b) More than 2 years and less than 5 years*
   - *c) More than 5 years*
   - *d) Most of my life*

2. **Did you use SL consultation times during this unit of study?** (please circle)
   - *a) Never*
   - *b) Yes, only once*
   - *c) Yes, more than once but less than 5 times*
   - *d) Yes, more than 5 times*

3. **If you answered (a) or (b) in question 2, what are the reasons for your answer, i.e. for not using SL consultation times?**

4. **If you answered (b), (c) or (d) to question 2, Please rate the following statement:**

Consultation in SL was beneficial for my learning (please circle):

Strongly Agree *Agree* *Neutral* *Disagree* *Strongly Disagree*

5. **Would you recommend using SL in conjunction with any future courses?** Yes No

6. **What are the best aspects of using SL in this course?**

7. **What are your suggestions for improvement?**

Figure 7. Questionnaire used to evaluate usage of SL in the unit of study.

B. Student Feedback

There were 24 students enrolled in this unit of study and the response rate to the questionnaire was 92%. For Q2, 23% said they used SL consultation times more than once during this unit of study. For Q4, 36% (i.e. strongly agreed with agreed responses) said SL was beneficial for their learning. This shows a lower level of usage than expected and also a lower level of accepted as indicated by the low positive response of Q4. However, it is interesting that for Q5, 67% still recommended using SL in conjunction with any future courses.

Question 1 was placed in the questionnaire to understand the relationship between competency in spoken English and usage of SL. This provided an interesting result when this was viewed in relation with Q5. Of the students who said they have spent 5 years or less in a country where English is a main language, 80% recommended using SL in conjunction with any future courses, while students who said they have spent more than 5 years in a country where English is a main language, only 25% recommended using SL in conjunction with any future courses. This rather expected result showed that students who lack competency in spoken English regard SL as a valuable tool for their learning.

Several questions in the questionnaire were open-ended allowing students to express their views in writing. The main reasons for not using SL consultation times were found to be due to technical limitations with computers (video card memory requirements in particular) and networking (Broadband internet required for comfortable downloading), which could explain the low response obtained for Q4. Several positive comments were received in reply to Q6. These included:

"User feels more free to ask questions."

"We don't feel the pressure of face to face interaction, & can develop our question more focusly."

"Availability beyond class hours is always beneficial."

"I can see a future in online/virtual learning. It is very convenient and one day can be optimised to allow operation of plants at home or overseas even,…."

In reply to Q7, recommendations were made around improving technical abilities of computers as well as a number of students commenting that SL should not be used solely and should not replace the real classroom, a view shared by the author.

C. Lecturer's Feedback and Remarks

The author (lecturer) found the use of SL to be a pleasant experience. It provided stimulation and raised the level of interest in the project at hand. Students moved from initially seeing SL as a fun tool to later in the course seeing it as a valuable and useful consultation tool. This was evidenced by the fact that they would be logged on and waiting on several occasions for the lecturer in SL and wanting to ask questions.

The development of the laboratory came at a cost to virtual world building consultants. This was not a cheap exercise. It is envisaged that a typical laboratory with standard tools and objects would arrive at a cost of about $5,000-$10,000. Consultants fees vary depending on quality of work as well as on requirements and one could easily end up with a much larger bill. Several advanced requirements could be incorporated and are continuously developing. It is envisaged that once the SL learning curve is overcome, several ways to optimize the cost could be worked out. Teaming up with others, for instance, to build a space could become a worthwhile exercise. Having said that, one is warned not to invest heavily upfront in development. A slow approach is useful. Virtual worlds and related technologies are continuously evolving and newer environments are surely set to be released in the future which could make other environments obsolete. Will Google for instance do something about this and create its own virtual world? This would, considering Google's dominance across the Web, be set to have a disruptive effect. It is though a development to look forward to.

There are current limitations in using SL. This was restricted in this unit of study to consultation times and student-student interactions. The use of realistic process simulations, while ideal, is still limited and any useful solutions are still far off in the future. It would be of interest to interface SL virtual plants with simulation engines as well as with real plants. This would allow a higher level of interaction between the student and the virtual processes. The author is currently exploring ways to attack this problem.

There are interesting aspects of interaction with students in SL. Several students were observed to show a higher level of confidence in asking questions in SL and raising discussions. This aspect was regarded as important. Considering that SL provides voice chat as well as written chat, there is envisaged to be no disadvantage to students towards learning to speak the new language. The lecturer however would need to encourage voice chat.

Finally, it is not the intention of the author to replace the real physical laboratory with a virtual one, and this should never be any educationalist's goal. Rather, the virtual laboratory is a complementary environment that support and deepens learning. So, it is not a question of whether one should be using virtual worlds for education or not, but rather, how does one use such for education. For example, it would be very useful to have the student visit the virtual laboratory the night before the physical laboratory exercise is scheduled. Going through the virtual laboratory and the learning materials associated within it inside the virtual world provides the student with a confident approach and a leap ahead in learning prior to the lab.

V. Conclusions

This paper presented and discussed the development of a virtual world in SL for learning Process Dynamics and Control. Various aspects of the environment were discussed highlighting the features it offers from the pedagogical point of view. The successful use of SL in the unit of study Process Systems Engineering was described. Feedback from students was collected through a questionnaire which showed students to have a mixed view about the use of virtual worlds. More than 90% of students who have spent 5 years or less in an English speaking language recommended the use of SL.

The primary hypothesis that "learning is enhanced using 3D virtual worlds" could not be categorically confirmed, however, the new experience gained showed a tremendous level of possibilities for engaging and stimulating students.

Several recommendations for using virtual worlds in the educational context were presented, importantly, (1) not to invest too much and too quickly into building inside these environments due to the rapid pace the technology is moving at, and (2) to ensure that the physical laboratory is not replaced by the virtual one.

Acknowledgment

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Virtual University as a Role Playing Game

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Abstract— **Research and development in design of games for education focus on understanding better what features of games can be inherited to further motivate students and simultaneously improve learning outcomes. Since, a common design standard is not available for educational games solutions are usually carried out by an ad hoc process. In this paper, a novel approach to design this kind of games is presented taking into consideration key features of the most successful massively multiplayer online role-playing games (MMORPG). The proposed design incorporates fun and learning through the key ingredients of MMORPGs that make them 'addictive' keeping the players constantly motivated. Our main contribution is to suggest design issues that should be taken into consideration when designing educational games.**

Keywords: Educational games, Virtual worlds, Motivation

I. Introduction

The use of educational computer games in teaching has received significant attention for increasing motivation and for enabling other types of learning experiences than those offered by traditional teaching methods. Despite the fact that this approach is mainly used in the area of lower education [1], more often higher education schools and universities adopt similar teaching methodologies [2]. In designing any learning game, it is all too tempting to simply graft academic content onto existing forms. While this approach may work, many believe that in any academic discipline, there are elements that are fundamentally game-like. An educational game should put players in touch with what is fundamentally engaging about the subject, should help them build a scaffolding of core concepts, and should motivate them to go deeper. The main features of games that could be applied to education are already identified [3] as: lessons that can be practiced repeatedly until mastered, monitoring learner progress, closing the gap between what is learned and its use, personalization of learning, and clear goals. In addition, modern video games may develop higher order thinking skills such as problem solving, strategic thinking, analysis, planning and executing, resource management, multi-tasking, and adapting to changing work scenarios.

One of the potential roles of video games in education is recognized as effective learning paradigms [4]. For example, discovery based learning is an approach to learning that highlights learner's active exploration of a subject. The use of computer games for military training is a reality [5]. Research is needed to advance games for learning. These research need to determine how (1) to design learning games to deliver positive learning outcomes, (2) to develop tools to automate the process of developing games for learning, and (3) to propose methods and techniques to assess the knowledge and skills learners acquire from educational games. This paper addresses the above research problems, providing a novel educational computer game design based on the characteristics and the features of a role playing game.

The structure of the paper is as follows. After this introduction, we examine, in Section 2, the evolution of games for learning, the motivational aspects of learning end education, as well as basic design concepts of online multiplayer games. This leads us to propose, in Section 3, our approach where we present modeling framework based on existing massively multiplayer online role-playing games (MMORPG). In Section 4 we demonstrate our approach giving a design example on framework for educational games we are developing. In Section 5 conclusions are drawn.

II. Previous Work

The problem of designing educational games has been considered in the past [6 – 10]. Based on studies on learning procedures using games and psychological theories of motivation and learning, we combine them in the designing of educational games. In this section, we give an overview of these fields, emphasizing their critical aspects.

A. Background of educational games

Mayo in [4] suggested that video games may teach science and engineering better than lectures exposing potential to address many drawbacks of modern educational systems. It has been found that effective learning paradigms are supported by specific kinds of video games and improve learning outcomes. In [11] Bransford et al found that video games stimulate chemical changes in the brain that promote learning. Mainly it was found that playing video games stimulates dopamine release, which is a chemical precursor to the memory storage process. Further research on video games indicates that an online educational game gives teachers the ability to reach students where they live, with compelling video games that can deliver educational content would increase the time spent on learning. Also, it has been noticed that the development of educational games that integrate learning with video gaming technologies is increasing.

Few of the potential roles of video games in education are recognized as effective learning paradigms and collaborative tasks. Discovery based learning is an approach to learning that emphasizes learner's active exploration of a subject.

In educational games, story can be used to structure the players experience to achieve educational objectives. Example includes Storytelling Alice programming environment [10] for creating interactive 3D virtual worlds. While there are numerous efforts that games can be applied to learning, relatively few attempts can be found where principles of learning and motivation theories were explicitly followed a priori in design.

Computer games are used for training purposes by the army, companies and institutions. Defense Advanced Research Project Agency developed a universal, on-demand training wars program (DARWARS) as a lightweight training simulation. Airplane simulators are widely used to train pilots, racing games are provided e.g. in formula 1 to increase driver's performance. Furthermore, they may be utilised for research and evaluation of particular scenarios or conditions e.g. driving under the influence of alcohol.

B. Motivation in learning process

The human's social development is driven by needs for competence, autonomy, and association. High degrees of motivation require satisfaction of natural psychological needs and are directed towards what people find interesting or important. According to [12 – 15] the Self-Determination Theory (SDT) gives the following classification of motivation:

Intrinsic motivation – refers to doing an activity for the inherent satisfaction of the activity itself;

Extrinsic motivation – refers to the performance of an activity in order to achieve some separable outcome;

Amotivation - denotes the absence of motivation.

Motivation leads to the activation of efficient cognitive strategies for long-term memory issues like monitoring, elaborating, or organizing information. On the opposite, amotivation decreases memorization and personal development. Motivation appears to be a key asset to get actively involved in the learning process.

C. Multiplayer Educational Gaming

Games can be effectively applied in many learning contexts. They can engage learners in ways other tools and approaches cannot, and their value for learning has been established through decades of research. MMOs in the entertainment sector have been seen to attract and retain players; counting millions of active subscriptions to MMOs worldwide, [16].

Over the past decade, the interest in educational gaming has grown and the research that has been conducted to bring games into the classroom have advanced our understanding and led to a more widespread acceptance of educational games. As research indicates, it will become more common to see MMOs offering immersive, engaging experiences in a variety of disciplines. It will still require effort and thought to create appropriate spaces and design compelling problems, but the very nature of MMOs lends itself to use by many people, spreading the benefits to many students.

Another aspect of MMOs that is of value to the educational community is the types of activities they make possible. These games offer opportunities for both discovery-based and goal-oriented learning, and can be very effective ways to develop team – building skills. It is possible to design activities that cannot be completed by a single player; a group must work together to strategize, develop a solution, maximize the various talents of the team members, and execute their plan in concert to succeed.

Examples of massively multiplayer educational gaming applications across disciplines include the following:

•**Study foreign language and culture**. MMOs offer the opportunity for virtual concentration, not only in a visual or design sense, but also in reading, writing, listening, and even speaking. A world based on an ancient or modern culture could include quests that require players to read instructions, listen to non-player-characters speaking clues, and write their own responses or answers, all in a foreign language and in a setting that allows them to feel what it was or is like to be part of that culture.

•**Develop leadership and management skills.** Even in non-educational MMOs, leadership and management skills come into play. Research has shown that players who take on the responsibility of leading a guild (group of affiliated players) or a raid (smaller group of players who team up to complete a specific objective) develop skills which are transferable into their lives at work and at university.

•**Practice strategy and apply knowledge competitively**. Multiplayer games offer an opportunity for students to practice what they have learned. For example, free online games allow players to make business deals and build up their net worth.

III. Proposed Apprpach

In our approach, we are reusing ideas from MMORPGs inheriting all the available multimodal user interfaces combined with techniques used to increase the students' motivation and the learning outcome. In this section, we give an overview of the three main design areas of an online Virtual University.

A. The University: In the virtual community, each university would be responsible for designing facilities (e.g. virtual labs, virtual campus etc). These facilities would be utilized either by the employed lecturers or they may be rented by other educational institutes.

Universities would be able to establish collaborations with other institutions exchanging facilities and even more tutorials and assignments (quests). These collaborations could be either bidirectional or not depending on the established agreement, see figure 1.

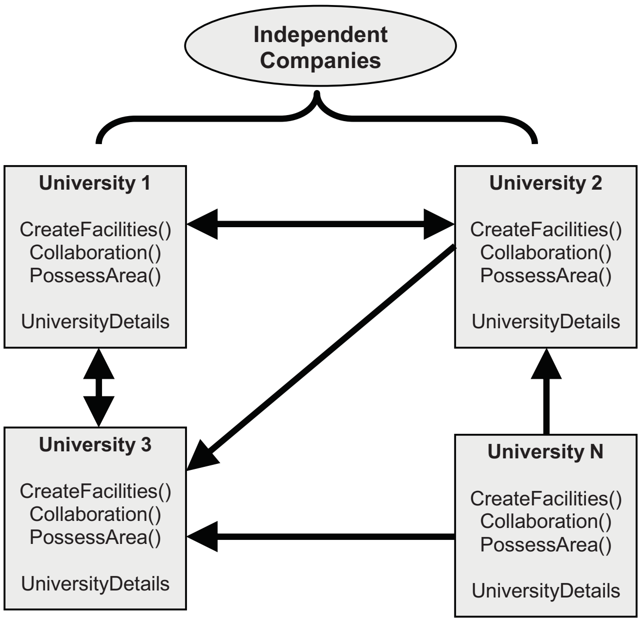

Figure 1: Diagram of established collaborations between institutions exchanging facilities, tutorials and assignments.

Third party companies could be employed by the institutions to design and implement virtual labs and facilities, building for example a virtual lab for dentists or engineers or music studies. Also, the virtual labs may be based on other educational games such as the Immune Attack [6] that is a PC-based single-player video game combining a realistic 3D depiction of biological structure and function with educational technologies for teaching immunology.

B. T*he Lecturers:* Each lecturer, creating an avatar, would be locating in the campus supplied by the affiliated virtual university. The avatar would be able to provide a set of 'quests' e.g. assignments, exercises and tutorials that may or may not require the use of the available virtual labs. For example, a lecturer teaching electronics may provide an exercise to implement a circuit using the virtual electronics lab and so on. Quests may be for individual students or for groups either from the same course or not. Tools would be provided to the lecturers in order to design and upload their 'quests'.

The second responsibility of a lecturer would be to correct and mark assignments that have been designed by lecturers over the entire virtual academic community of the same field assuming that marking instructions would be provided be the assignment's original creator. The marking procedure would be similar to the one used in conferences. Therefore, a list of topics of interest would be created for each academic avatar and based on these topics the appropriate course works would be assigned for marking.

C. T*he Students:* The first time a student logs into the system would be asked to create an avatar, confirm his affiliation and select a path ('race') e.g. medicine, computing, etc from the list provided by the university. Then a course ('class') would be chosen and the student would be ready to join the virtual university. Based on their path and course students would have access to a set of assignments, virtual tutorials either from their university or other institutes if collaboration has been established. A variety of assignments would be available (e.g. for one person, a group, with or without time limits etc) providing at the same time several options. When the students complete the coursework they return it to the lecturer's avatar from where they initially obtained it, ranking also the quality of the assignment, the available tutorials and the virtual facilities. The coursework would be automatically transferred to more than one randomly selected lecturers from any university for blind marking. According to their marks students gain points and move to the next level having access to more advance exercises ('quests'), facilities and tutorials.

Some additional features that could be integrated into the virtual university are the property ownership and prices both virtual and real provided to students with the best performance. Regarding the first feature, students may own a room in campus or share a house with classmates. Functionalities to decorate their rooms would be available. Useful tools or equipment may be parts of the virtual prices. Also, in-game visual displays can be used to broadcast such events including virtual interviews of the best students. The real prices can be scholarships, money or opportunities for further studies or collaboration with companies.

Another feature that will be integrated will be a talent system. Based on the results on their quests students may obtain talent points for example in mathematics, history etc creating a more unique character with specific expertise and capabilities.

D. *Companies*: Virtual stands of companies could be integrated into the Virtual University world, either for job advertisement that may include interview tests or as a research partner providing facilities and 'quests' to students. Companies would not be part of the assignments marking but it will be optional to join the students' evaluation system.

IV. DESIGN EXAMPLE

In this section an analysis of the proposed design is presented. The main classes and their relationships are shown in figure 2. The proposed game design is consisted of three main classes representing the University, the Lecturers and the Students. Companies are not integrated in the current version of the system. The key functionalities and properties are presented for each class. A university is consisted by lecturers, students and facilities with a set of courses to be provided. Each course includes a list of available modules with students and lecturers registered to them. This relationship would provide access to the corresponding 'quests' set, designed by the lecturers related to that particular module.

Regarding the platform that is used for the implementation of the proposed Virtual University, research was conducted and

157 students participated. According to the statistical analysis 70.18% of the students prefer to play MMORPGs on a PC, 15.79% on Xbox360, 14.03% on PS3 and with 0% on a Wii or a portable device. Also, 80.70% of the students would prefer to play the game on a system with nice graphics and with just 19.30% to prefer a web based approach with low quality graphics but higher mobility (e.g. player would be able to login form any system, computer, laptop or mobile, without any software installation to be required). Based on the above analysis C# and XNA were suggested as implementation tools providing the option to implement a game simultaneously for both PCs and Xboxes360 without sacrificing any graphics quality.

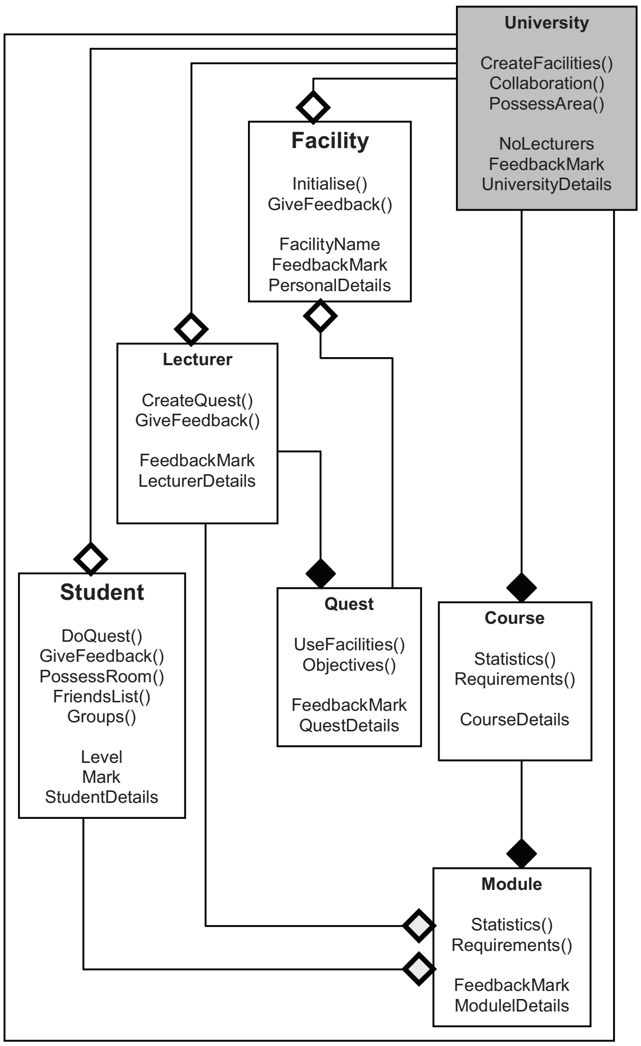

Figure 2: Main class diagram of the proposed Virtual University MMO game.

Based on the preliminary research MMORPGs were considered that provide more educational features compared with other types of games. In more details 42% of the students considered the MMORPGs above the average on an educational scale from 1 to 5. MMORPGs were regarded as high educational games by the 18% of the students and 40% below the average. Regarding other type of games, simulators (e.g. for airplanes and cars) and brain testing games were also considered as educational but for specific applications.

Significant emphasis is given on group quests either including students from the same course or not. From the analysis it was obtained that almost 60% of the students consider the group quests as the most important feature of MMOs, with the leveling concept coming second at 21%. The variety and the constant updating of the quests were selected by 12% of the students and the remaining was the graphics and the AI.

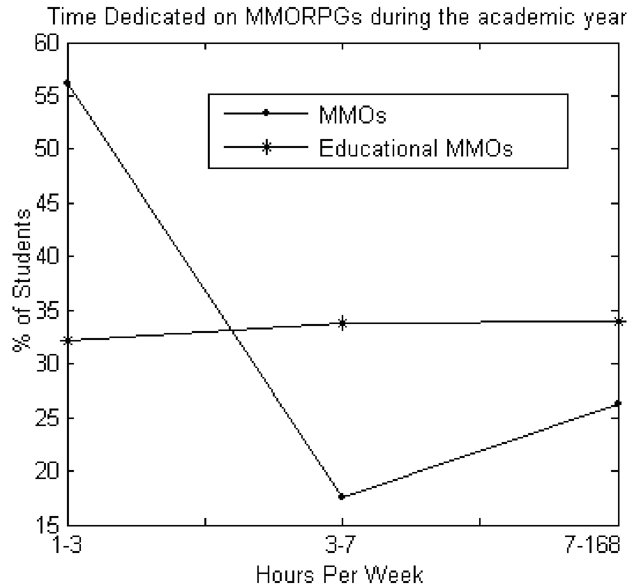

Figure 3: Percentage of students versus the hours dedicated on gaming per week for MMOs and educational MMOs.

During the academic year more than 56% of the students spend less than 3 hours per week on MMOs, almost 18% between 3 and 7 hours and more than 26% is spending above 7 hours. This trend is changing if the MMO game was part of the education with a significant part of students to dedicate more than 3 hours per week, see figure 3.

V. Conclusion

In this paper we propose a design for a virtual academic community based on the principles and the characteristics of a role playing game. The proposed design would provide lessons that can be practiced repeatedly until mastered, monitoring learner progress, closing the gap between what is learned and its use, and clear goals. In addition, the proposed video game design may develop higher order thinking skills such as problem solving, strategic thinking, analysis, planning and executing, team working and multi-tasking.

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Session 04D Area 4: e-Assessment and new Assessment Theories and Methodologies - Methods

Online assessment of practical knowledge in electronics laboratory
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An integrated system as a tool for complex technology learning
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Polytechnic Universitary School of San Sebastián (Spain); University of Vigo (Spain)

Experiments in evaluation: towards an eXtreme Learning method
Cuadrado, Félix; Dueñas, Juan C.
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Mixed e-Assessment: an application of the student-generated questions technique
Cannella, Salvatore; Ciancimino, Elena; López-Campos, Mónica
University of Palermo (Italy); University of Seville (Spain)

Online Assessment of Practical Knowledge in Electronics Laboratory

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Abstract—**Increasing globalization and opportunities for engineers around the world to work or study anywhere mean challenges for universities wanting the best students as well as for the companies wanting for the most skilled staff. The social and economic conditions of the country where the student has studied have an impact on his level of knowledge though the attained degree is similar in all countries. It is not enough to use scores as a base for decisions. Some tests for software courses, English language etc. exists. Now the challenge is to design and implement a common test to analyze the knowledge of the student/ test taker and certify him in performing laboratory work and operating electronic instruments. A solution to overcome the problem of recruiting companies in this global market as well as the universities to select the meritorious from worldwide would be by implementing a Common Electronics Lab Operation Test. A test with the operation of the equipment in electronics laboratory has importance as test takers are tested in their knowledge with practical equipment using simulated and remote labs which are identical to the operation of real. The testing system is proposed to be developed using latest remotely operated real labs.**

Keywords-knowledge Engineering; testing;

I. INTRODUCTION

Thousands of students are graduated with a bachelor degree in Engineering/Technology from universities worldwide every year. Increasing globalization make engineers work or apply for master studies anywhere in the world. This makes it necessary to evaluate the technical skills of the engineers. There are a wide range of universities worldwide where many of the students attain the same qualification at the end of their course but their technical skill might not be equal. This motivates to establish a common knowledge level for all electronic bachelor degrees worldwide. There are a number of exams available for testing theoretical knowledge. A survey of such tests and the reasons for testing practical skills is explained in the next section. Section III illustrates the present and future trends in laboratory facilities. The Proposed system of assessment defined in section IV is a solution to evaluate the practical skills of the students and its implementation part is described in section V.

II. PRESENT WAY OF TESTING SKILLS FOR ADMISSION TO HIGHER STUDIES IN DEVELOPED COUNTRIES.

At Present for assessing the student's knowledge for master studies many universities consider GRE, GMAT, and TOEFL/IELTS. IELTS/TOEFL is used to test the skill of the test taker to speak in English as a foreign language [1]. These tests help the student to develop the test takers speaking as well as essay writing in English language [2]. This test is necessary as the student from a different geographical place has a local language and his adaptability to sustain in other country is to be analyzed. GMAT measures the verbal, math and analytical skills of the student which is really required for a MBA admission [3]. GRE General Test which is considered as an admission criteria for many Engineering courses in some of the developed countries analyzes student's verbal and quantitative ability [4].

GRE subject tests are available to test the knowledge in 8 specific fields of study such as Physics, Math, and Computers etc. These subjects are multiple choice questions [5]. The GRE subject test is a good solution for analyzing the technical knowledge but it does not consider the practical ability of the engineers to develop experiments. This exam does not use any simulated environment for testing the test takers practical knowledge.

GRE General Test has nothing to do with the students Engineering discipline or his technical competence in his field of study. The score in this test is based on high English vocabulary and math.

Many industries have a grading scheme which applies for applicants depending on their scores. This hurdle has been overcome by many software industries which have implemented certifications for instance CCNA [6], ORACLE, DBMS, Lab View, etc.

III. PRESENT AND FUTURE TRENDS OF LABORATORY FACILITIES IN EDUCATIONAL INSTITUTIONS:

There is a vast development in the field of technology which has its impact in the field of education. In Electrical Engineering education from many years traditional laboratory equipment are being used such as oscilloscopes, function generator's, multlimeters, components, breadboards etc. In the coming years the traditional laboratories all over the world will be offered online (most of them at present are replaced by the simulated lab benches) which is really a good trend [7]. This helps the experimenters to analyze and understand the behavior of the circuit in a better way and gives the possibility to experiment as he likes by just making a circuit of his interest, adding the components from the components palette provided by the software and run to check its output. This decreases cost, increases time flexibility for making experiments and better research capabilities by analyzing circuits with many options, individually or by a group [8].

IV. DEFINING THE TEST:

A certifying test in electronics laboratory has very high importance as it does not contain theory or a multiple choice question like many other examinations. Here the test takers will be tested in their knowledge with practical equipment. The test taker can clear this exam if and only if he has sound knowledge in using the laboratory equipment. In this proposed exam there are three levels of knowledge testing, Basic, Advanced and Professional.

A. *Description of the proposed levels of the exam*

Basic level: Here the test taker is checked with his knowledge in basic circuits. His practical knowledge is tested by giving the circuits with errors and asking him to correct the circuit to generate output.

Advanced level: Here the test taker has to configure the circuit by him. His practical knowledge is checked in configuring the circuits himself and generating output.

Professional level: In this level the test takers are asked to correct the circuits and also configure them. The level of complexity increases.

B. *Syllabus for the proposed tests:*

Basic level: Any test takers with a passion towards electronics and his interest towards developing electronics can take this exam. In general this part of the exam focuses on the characteristics of diodes, transistors, oscillators, Rectifiers, operation of Oscilloscope and Function generator etc.

Advanced level: This level has an eligibility condition that the test taker has a qualified bachelor's degree (Electronics) or he has cleared the basic level in this exam. This part of the exam focuses on clippers, clampers, gates, OP AMP, characterizing LED's and timers etc.

Professional level: This level has an eligibility condition that the test taker has a qualified bachelor's degree (Electronics) and cleared the advanced level of the proposed exam. This part focuses on overall syllabus from prior two levels including with Flip Flop, shift registers, logical operations such as converting of ASCII to BCD vice versa and micro controller programming.

These tests provide the test taker with an assessment to his knowledge in operating the electronic laboratory equipment. Passing this exam gives electronic professionals the chance to prove their practical knowledge in operating electronic instruments and expertise.

V. IMPLEMENTATION OF THE PROPOSAL:

This approach of testing can be done using simulated and remotely operated real work benches. Primarily let us consider the reasons whether to use a simulated approach as a solution for this proposed exam or a remotely operated real lab.

Simulated labs already exist from long time based on mathematical calculations. These labs are virtual and made up of software simulations during the last decades simulated labs are encouraged in Engineering education due to the fact that the traditional labs are costly to implement and maintain and also due to the belief that they can replace the real labs [9].

Real labs are indispensable in Engineering Education as a means of developing skills to develop with physical process and Instrumentation. Remote labs have proven valuable for a more efficient exploitation of laboratory resources and can be shared among participants form different places. Having the remote experiments ready all the time, the remote lab concept also provides a tool to sustain the shift towards a student – centric teaching approach, which is more and more relevant in higher education, nowadays [10].

In this proposed assessment of practical knowledge using real labs, the authors are considering 5 real labs such as VISIR, REL, WebLab-Deutso, iLabs etc and a brief description of their functioning is given as follows. One good example of remotely operated real lab is ―VISIR System" developed by the Open Labs, BTH [11]. The only difference between this remotely operated real lab and traditional lab is that the student can not feel the instrument by touching it. Virtual front panels of the instruments in the laboratory are displayed on the student's computer screens which make the students feel as if they are using traditional laboratory.

1) Brief description of the open labs electronics laboratory in BTH, Sweden

Here we can find all the resources needed to make electronic experiments, right here in the browser. As shown in Figure 1 all the basic equipments such as oscilloscope, multimeter, function generator, power supply and a number of electronic components are supplied where it is possible to build circuits on virtual breadboard [12]. The circuits built on the local client software are sent to the server and the measurement is done on the real equipment and the measurement results are displayed [13].

Figure 1. VISIR system developed by BTH,SWEDEN

2) Brief description of the WebLab-deutso in University of Deutso, Spain

WebLab-Deusto is an open-source distributed Remote Lab continuously developed at the University of Deusto. It makes possible to do real experiments with FPGA, CPLD, PIC microcontrollers, etc to a certain group of users through any computer network, such as Internet. The experience of using the experiments remotely is exactly the same as using them in a traditional laboratory. The Figure 2 below shows a webcam image of the CPLD being operated remotely and its display to the experimenter [14].

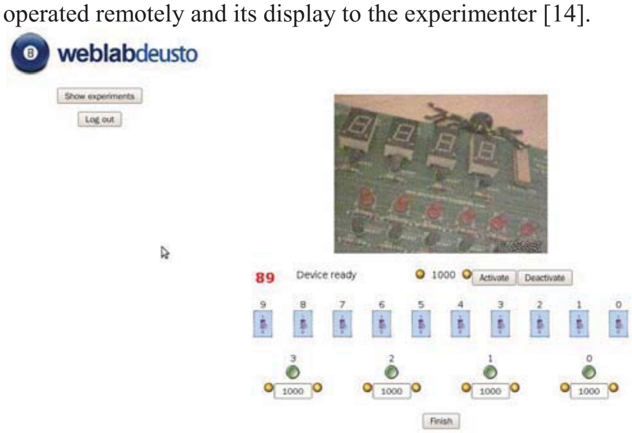

Figure 2. Web cam image of the remotely accessible lab developed by WebLab-Deutso.

3) Brief description of the iLabs in MIT, USA.

iLabs provides an open portal to selected remote laboratories and is developed at the MIT University, USA sponsored by Microsoft Corporation. It makes possible to do real experiments with Microelectronics Device Characterization, Dynamic Signal Analyzer, Microelectronics Device Simulator, etc to a certain group of users through any computer network, such as Internet. The experience of using the experiments remotely is exactly the same as using them in a traditional laboratory. The vision of iLab is to create a worldwide network of shared laboratory instruments and educational materials [15].

4) Brief description of the Remote Electronic lab and Remote Lab for E-Learning in Microprocessors.

The ―Remote Electronic Lab” (REL) is a system for carrying out electronic experiments via the Internet in the context of distance education. It is based on remote control of real laboratory instruments. Figure 3 displays the image of the electronic instruments that are connected to the server to operate remotely.

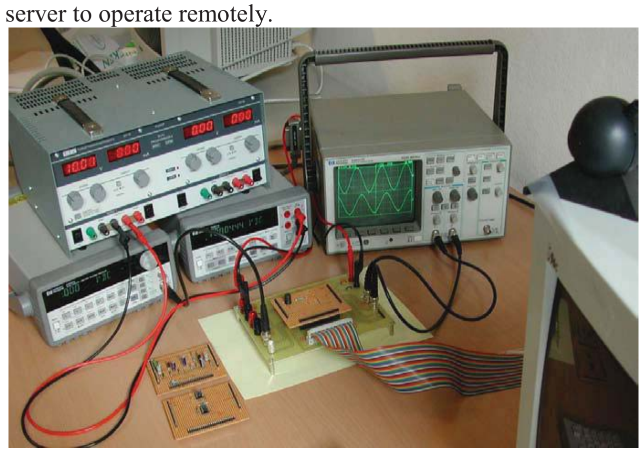

Figure 3. Remote Electronics Lab at CUAS

The Figure 4 consists of a microprocessor remote lab which was developed for the presence learning and teaching as the starting point. The mock-up was used to implement Problem Based learning methodology in both undergraduate and master subjects [16].

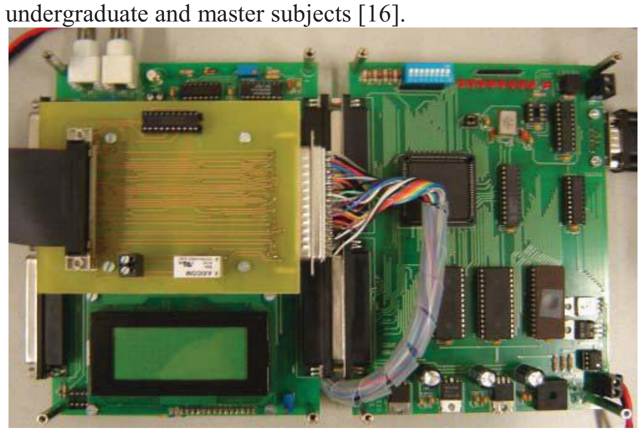

Figure 4. Web image of a Micro Controller that can be accessed remotely

In face to face learning environment users in remote are allowed to download their own code, monitor and control the registers, memory contents, executing the program and reading the display output for example pressing a key on the keyboard and observing the response of different switches.

This exam can be implemented by the engineering associations such as IAOE ―The International Association of Online Engineering" & IEEE ―Institute of Electrical & Electronics Engineers" combined together formulate syllabus for different levels of certification. Depending on the qualification of the test taker as electronics engineer the level of certification is assigned (for instance bachelor or master etc.) The syllabus in general is the course curriculum the student has studied for attaining the degree.

VI. ADVANTAGES

International online laboratory skills testing exam will be a valid and reliable indicator of true skills in electronics laboratory for education, professional accreditation and is very helpful in succeeding as a professional in the electronics laboratory for experimenting with the electronic equipment and provide measurable benefits to the employer. This type of exam or certification helps the test taker to differentiate him with others with the similar qualification in the present global market as well as improve his practical skills.

For E-Lab professionals each certification level signifies a benchmark of experience and expertise recognized with the electronics industry. The proposed certification exam validates the ability of the test taker to install, configure, operate, and troubleshoot with the electronic equipment, including implementation and verification of connections to various electronic components. Earning certification adds credibility to test takers expertise in using the electronic equipment. For organizations and hiring managers, certification can be a credible prerequisite to identify the expertise for hiring, promoting, and outsourcing decisions. This test certifies that that the test taker is technically competent to handle with the electronic instruments so as to promote sustainable society.

VII. CONCLUSION

The concept of evaluating skills of individuals from different countries and providing opportunities based on their knowledge exists since long time and now is the time to extend it to the electronics engineers. This proposed test brings valuable knowledge outcome from the students, rewards to electronic professionals and the companies employing them, the universities admitting them and Research oriented institutes to access the applicant's knowledge in the area of Electronic design and implementation. The fruit of knowledge grading through individual subject related examinations which is presently enjoyed by many software companies should not be limited to their industry itself but to be extended to other core fields such as electronics, mechanics, chemical, electrical, etc. This test enhances skills of electronic professionals which is a benefit for both the employee and employer. Through this paper the authors try to get it to the notice of the engineering organization worldwide that the time has come to develop qualitative engineers and to promote sustainability.

ACKNOWLEDGEMENT

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An Integrated System as a tool for complex technologies learning

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***Abstract*—This paper describes a integrated computer-based learning system improving engineering teaching and learning of complex technologies. It combines a tutorial with a virtual laboratory and a self assessment tool to achieve a self-learning system. The tutorial is a hypermedia document linking different concepts of Electronics technology and combining them with a virtual laboratory. This virtual laboratory is made up of a set of virtual experiments with a user-friendly graphic interface and interactive simulated electronic instruments relating practical and theoretical concepts. The self assessment tool combines a test with each experiment of the virtual laboratory. The whole system matches the constructivist theory and constitutes an interactive computer-based complex tool.**

Keywords-component; integrated learning system; computer aided learning; virtual laboratory; self assessment too;.

I. INTRODUCTION

Engineering teaching and learning has turned very difficult because present technological solutions including many interrelated concepts tend to become very complex [1] [2]. Consequently some engineering education experts [3] [4] claim that it is necessary to develop new education methods using information technology tools to improve teaching and learning. Using these methods it is possible to combine theoretical and practical activities [5] [6] in order to learn technology synthesis methods using actual products as working examples [7]. There is also a general agreement about the need of new teaching and assessment strategies to enhance competence-based learning [8]. The whole system matches the constructivist theory [9] [10] [11] [12] and constitutes an interactive computer-based complex tool enhancing competence based learning.

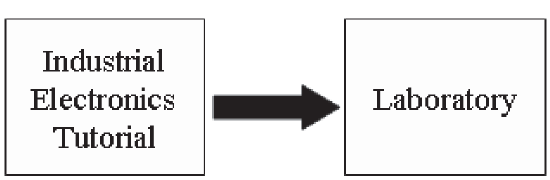

Figure 1. Learning process of complex technologies at present

At present, complex technologies learning comprises two steps. First, the students learn theoretical concepts attending lectures and studying a tutorial book and second, they perform a set of tasks in a laboratory. However, this process has several drawbacks:

- Tutorials included in a book do not give enough information about the dynamic behavior of the different types of circuits and systems.
- Students have insufficient knowledge about commercial components, assembly techniques and measurement instruments. Assembly errors and component damage are common during laboratory classes.
- Students do not know if their knowledge about theoretical concepts is good enough.
- Students have no experience on testing different components behavior.
- It is not suitable for asynchronous distance learning

This paper describes a computer-based system improving the engineering education process. This system is called "integrated learning system" because it combines three subsystems (see figure 2):

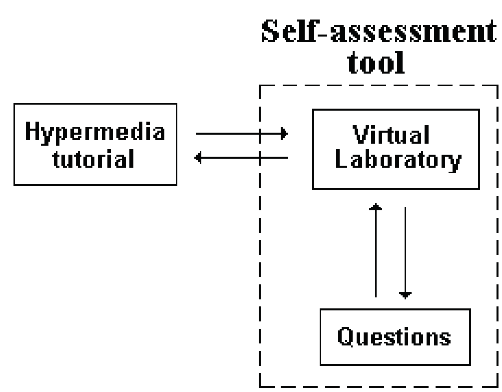

Figure 2. Hypermedia integrated learning system block diagram

A. Ttutorial

It is a hypermedia learning system structured into chapters, sections and subsections. The different subsections are associated with one or more virtual experiments through a user-friendly graphic interface and some interactive simulated instruments relating practical outcomes with theoretical concepts. The student can execute each experiment at the point indicated in the tutorial after studying the corresponding theoretical concept.

B. Virtual Laboratory

There are several kinds of virtual laboratories with different application purposes. The virtual laboratory of the integrated learning system comprises a set of virtual experiments. Each experiment is a pedagogical interactive simulation using just a few computer resources and can be integrated with some other software application.

C. Self-assessment tool

This is a computer tool combining one or more tests with each experiment of the virtual laboratory. In each case the student selects what he thinks is the correct answer and the system does not provide the solution but shows him the experiment outcomes, giving the possibility of verifying his answer. In this way he can learn from his mistakes [13].

As an example an "Electronics Integrated Learning System" has been developed including a virtual laboratory and a self assessment tool.

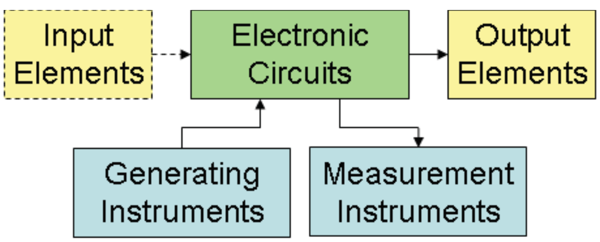

Figure 3. Block diagram for of the interface of the virtual laboratory of the Electronics Integrated Learning System

II. VIRTUAL LABORATORY

The Electronics Virtual Laboratory has the following characteristics:

- A user-friendly graphic interface.
- Interactive simulated instruments with a functionality similar to that of the actual instruments.
- Relates practical with theoretical concepts through a selected set of experiments.
- Each experiment is a pedagogical interactive simulation using just a few computer resources and can be integrated with some other software application.
- Provides destructive experiments which are not possible when using actual electronic devices.
- It has self-test capacity.
- It is scalable to add new performances.

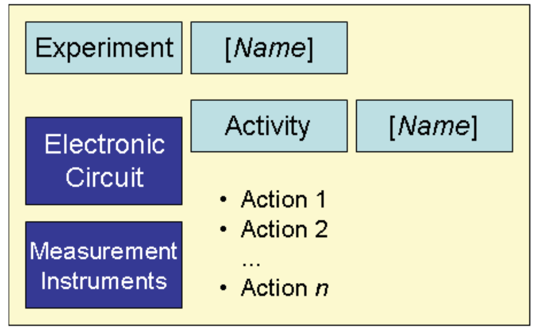

Figure 4. Block diagram of the experiment user interface

The user interface includes the different instruments used in the actual laboratory. These instruments are connected to some suitable test points. Figure 3 shows the block diagram for the user interface of the electronics virtual laboratory, including generating instruments, measurement instruments, input and output elements, and the electronic circuits under test.

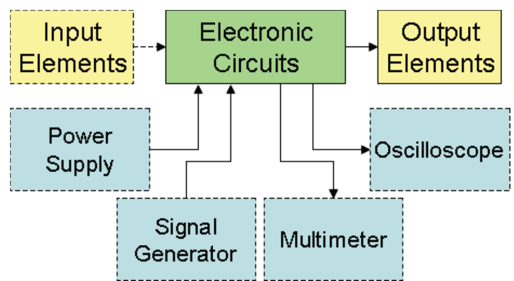

Figure 5. User interface block diagram of the Analog Electronics Virtual Laboratory

Each experiment includes the description of the activities to be accomplished by the student, as shown in figure 4.

The main parts of Electronics are Analog and Digital Electronics, and a Virtual Laboratory has been developed for each one of them.

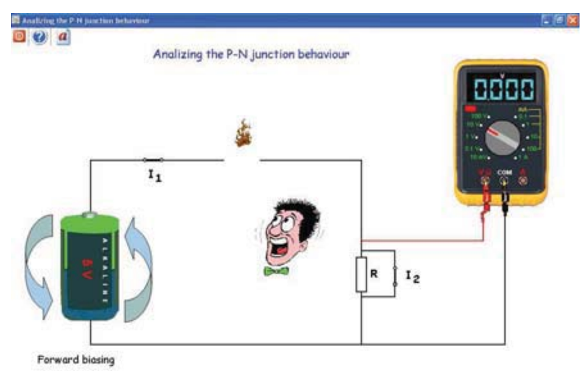

Figure 6. PN junction destructive experiment behaviour using a multimeter

A. Analog Electronics Virtual Laboratory

Figure 5 shows the user interface block diagram of the analog electronics virtual laboratory experiments including a signal generator, a power supply, a multimeter and an oscilloscope. All the experiments use a power supply, and depending on the characteristics of the experiment, one or more of the other three available instruments.

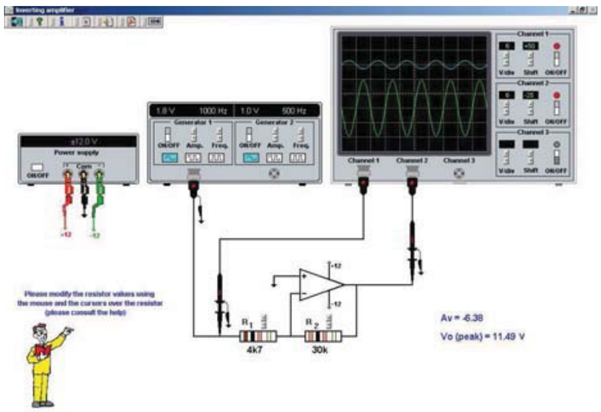

Figure.7 Inverting amplifier experiment using a signal generator and an oscilloscope

The multimeter is used in the experiments where only DC signals are involved. As an example, in figure 6 shows the experiment analyzing the behaviour of the PN junction. This is a destructive experiment where the user can verify what happens when the PN junction is directly biased without a current limiting resistor.

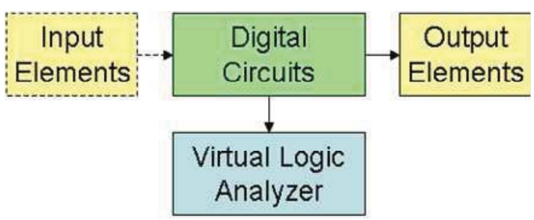

Figure 8. Digital circuits virtual experiment block diagram

The oscilloscope is used when the experiment includes time varying signals. The student can select the type of waveform, the frequency and amplitude of the signal generator output and the scope main parameters. He can also change the resistor standard values using the mouse. As an example, figure 7 illustrates the experiment analyzing the behaviour of an inverting amplifier.

B. Digital Electronics Virtual Laboratory

The digital electronics virtual laboratory (see figure 8) has an interactive graphic user interface including a digital circuit and a virtual logic analyzer to visualize the evolution of the different input and output signals.

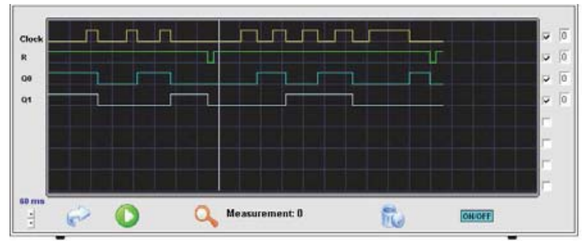

Figure 9. Virtual logic analyzer interface

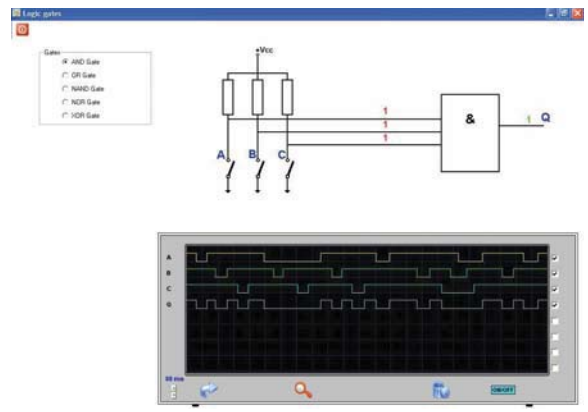

Figure 10. Experiment of the different logic gates

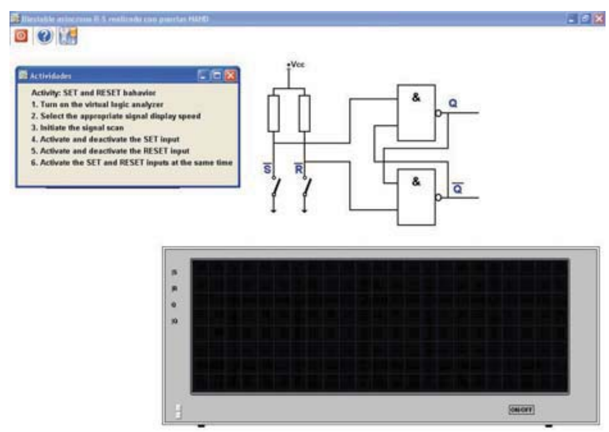

Figure 11. Student interface of the experiment "R-S latch with set priority"

The virtual logic analyzer (see figure 9) has 8 channels. It works like an actual logic analyzer, including user programmable signal display speed. Signal display can be stopped at any time. In this situation, when the user clicks on the magnifying glass a cursor facilitates signal level reading on any point of the virtual logic analyzer screen. The virtual logic analyzer is a suitable tool to analyze the behaviour of the different combinational and sequential circuits. Figure 10 shows the experiment describing the behaviour of the different logic gates. The student can select the type of gate and the logic level of the inputs. Figure 11 shows the R-S latch behavior including its activity description.

III. SELF ASSESSMENT TOOL

The analog and digital virtual experiments can be used by the professor in the classroom but to become a useful tool improving the user self-learning capacity they must be combined with an assessment tool.

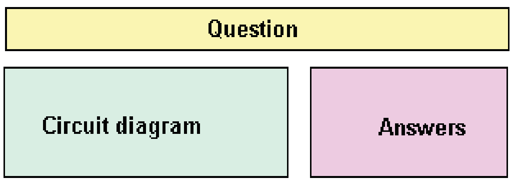

Figure 12. Assessment tool user interface block diagram

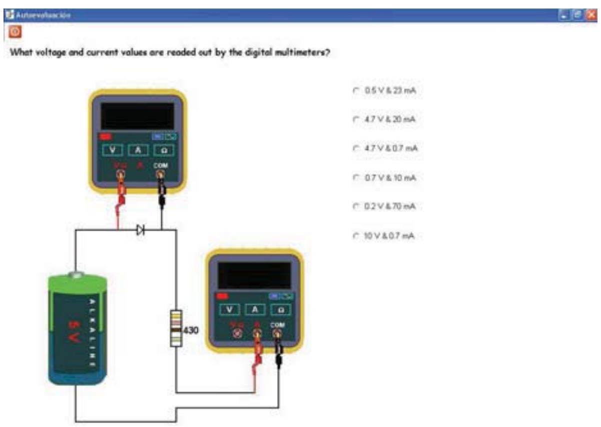

Figure 13. Example of the user interface of a self assessment question

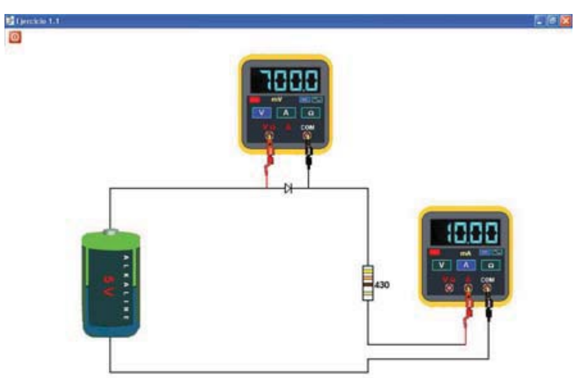

Figure 14. Eecuting the experiment after answering the question

As shown in figure 13, after studying the hypermedia learning system combining the tutorial and the virtual laboratory, the student executes the self assessment tool. This tool is a set of multiple choice questions. Figure 12 shows the self-assessment tool user interface block diagram combining one experiment schematic, one question and the list of the possible answers. The student must select the answer that he thinks is correct. The tool does not give him the correct answer but it presents the experiment asking him to execute it to verify if the answer is correct. In this way the student has the opportunity of executing the experiment before giving the definitive answer. This process constitutes a double assessment using not only the question but also the experiment.

Figure 13 shows, as an example, one question about the semiconductor diode. Answering this question the student demonstrates his expertise about the semiconductor diode behaviour when it is forward biased. The student must choose one of the possible answers and then the tool executes the correspondent experiming. In this way the student can make voltage and current measurements again to verify if his answer is correct in the same way as in an actual laboratory (see figure 14).

IV. CONCLUSIONS

The integrated learning system described in this paper is an enhanced active learning rich environment [11] increasing the self learning capacity of students. The virtual laboratory is structured as a set of learning objects and it can be combined with different tutorials. The self assessment tool can also be integrated with some interactive learning management system such as for example Moodle.

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Experiments in evaluation: towards an eXtreme Learning method

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***Abstract*— In the last years, the field of education has advanced boosted by the introduction of Information Technologies. However, these advances have occurred to a lesser extent in the support of evaluation and assessment of students' learning, even when the improvements in evaluation would enhance the whole learning process. In this paper, the processes involved in assessment in engineering university learning are identified, described, reviewed and analyzed in order to ensure fast feedback to the students. A method for evaluation called eXtreme Learning is introduced which builds upon highly granular and continuous evaluation, integration of evaluation within the general learning process and fast feedback of evaluation results to students. At the same time, the method keeps some principles of traditional learning considered mandatory for its application in university education, as they certify the level of knowledge of the student.**

***Index Terms*— e-Assessment, educational methods, computer assisted assessment.**

I. Introduction

The integration of Information Technologies has contributed greatly to the advancement of the majority of educational processes such as information gathering, cooperative learning, distance education, housekeeping, etc. In contrast, the support of evaluation and assessment of students' learning has received less attention by the research and practitioners community.

In the rest of the paper, a model of the activities typically involved in university learning evaluation are presented; then we perform an analysis on such process in order to improve the feedback to students. A series of experiments in real university settings has been done, whose results are discussed. As a consequence, an evaluation process called eXtreme Learning is introduced, which allows applying fast feedback loops into the traditional university learning process. At the same time, the method keeps some principles of traditional learning considered mandatory for its application in university education, as they certify the level of knowledge of the student.

The method relies on the application of well-known principles of pedagogy, such as choosing the proper granularity for each learning activity in contents and students' effort, ordering the knowledge acquisition following a logical path, enforcing the gathering of key knowledge, putting the knowledge into practice (particularly adapted to engineering education), evaluating the core concepts, converting the evaluation into a learning experience, and performing additive marking. Also, the role of e-learning technology is discussed, as the method, having a cornerstone on fast evaluation, cannot be applied without the proper technical support.

This article describes the results obtained in the application of the proposed method to a first course in computer programming in engineering syllabus over two different semesters. The specific characteristics of the subject impose additional requirements as students must face different studying conditions and context, while keeping at the same time the motivation for the kind of studies they have chosen. The application of the method has been maturing for a number of years as the selection of the proper granularity and sequence of learning contents was guided by a "trial and error" strategy. Then, we applied the method in the computer programming in the first course of Telecommunication Engineering in Universidad Politécnica de Madrid (UPM), for two different semesters, over a large set of students on a real setting. The control group exhibited better levels of success (percentage pass/total of students) and better learning results (marks over the whole subject) in the two semesters.

Outcomes from the experiences provide hints about the usefulness of the approach. Also the potential problems and drawbacks in the application of the approach are discussed.

II. Educational Assessment

In order to track the outcome of the learning process it is necessary to evaluate student's process. This is achieved using a wide range of methods for evaluating students performance and attainment including formal testing and examinations, practical and oral assessment and classroom assessment among others [1][2].

The role of evaluation activities in the university education has been analyzed as far as the second half of XIX century, by the philosophical school of K. F. Krause. At that time, throughout all Europe there is a strong interest on pedagogy at university that identifies the concept of traditional exam as one of the key elements to be replaced or complemented by other evaluation methods (such as continual evaluation), in order to improve students motivation and get closer to the actual knowledge [3].

As regards evaluation, pedagogues usually distinguish between summative and formative assessment [4]. The first is usually applied once the learning period has been completed, is driven by the academic staff, can be verified and marked,

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validating that the knowledge /objectives have been obtained. On the other side, formative assessment is applied continuously, and intends to help the student improve the learning, providing feedback and recommendations on his own taken process.

Some tendencies try to conciliate both approaches; among them, “Authentic Assessment” [5] focuses on the acquisition of competencies and the evaluation of this achievement. Thus, evaluation must be a planned integrated process related to professional competences. However, up to our knowledge, no formal efforts have been performed in order to combine summative and formative assessment into a single method that gets the best of both and avoids the problems they face.

In traditional evaluation process –at least in the university education-, whose goal is to qualify or certify the level of knowledge of the student at the end of a learning time, only summative assessment is applied, consisting of a final exam at the end of the teaching semester. This evaluation method has been used extensively due to some of its characteristics: it allows comparison in the group of students as well as the checking of a knowledge threshold, it is cheap in organizational terms; it is predictable in methods, secure and fair. It is also mandatory by legal conditions in some universities.

The traditional evaluation process has been improved in the last years by the introduction of the “continuous evaluation” approach, in which the evaluation activities are performed throughout the learning period (not only at its end). These processes bring the advantages of formative assessment for improving the quality of student learning. Its application allows for: increased feedback to the students about their learning process, increased motivation, feedback to the staff about the quality of teaching, consideration of evaluation activities as learning (it is also formative) [6]. It is a difficult method, as many times the evaluation gets uncoupled from teaching and from learning, it is time consuming, it may be unplanned, increases housekeeping overhead in the learning process, and it may put strong pressure to students, which is clearly undesirable to retain them inside the academic environment (the “retention problem” refers as the capabilities to keep students focused on the syllabus they have chosen), as stated in [7].

However, the incorporation of formative assessment into course assessment presents several challenges to improve the formative capabilities of the process, such as the adaptation of learning objects to the characteristics and context of each student; or the consideration of learning paths, defined as the sequence of consumption of learning objects by the students. This sequence defines a path or trajectory of navigation on the set which can be defined in the learning planning activities, chosen by the student, or explored by social algorithms. In any case, there is an optimal trajectory, and the actual one that must be compared with the ideal in order to know the quality of the learning process, qualify the student, and suggest corrective actions. All this can be considered as a control loop, and as such, a fast feedback and an adequate response to deviations make the system stable. On the technical side, some of the outcomes related to this theory are: the definition of learning paths, the algorithms to adapt these paths to each student, and the resources for the evaluation of the knowledge.

The usage of Information and Communication Technologies (ICT) on evaluation is increasingly growing, leading to the concept of e-assessment as the study of the usage of computers and related technology within the assessment process. It has many advantages over traditional (paper-based) assessment, as it automates most of the repeatable tasks non depending on human judgment, such as getting the answers provided from students, storing them, marking or communicating results [8]. There are some successful systems supporting e-assessment based on forms or questionnaires, such as WebCT.

Particularly useful are those systems which integrate evaluation into the general learning process: learning Management Systems (LMS), also known as learning platforms. They are based on a Web server providing software modules for administrative and tracking processes on a learning system. These kinds of systems also ease distributed collaborative learning from prepared activities and contents; both in synchronous and asynchronous way, based on Internet services. Students follow the lessons, perform the scheduled activities, communicate with professors and other students, and produce statistical and marking records. Some LMS are Blackboard, Moodle and Claroline .

However, being powerful tools, LMS are usually devised for its usage in distributed settings with students spread across a region. Computer security measures, such as the usage of password authentication are in place. But ensuring the student gave answers to evaluation questions without help is still a process requiring human intervention (traditional examination in a certain place in which the student gets reduced communication capabilities is the best example). There are some evaluations that provide legal effects and therefore security and reliability must be preserved; so far these are performed purely in the summative mode without the help of ICT infrastructures.

III. Evaluation process

Therefore, we focused our efforts on the integration of formative and summative evaluation in the context of university education; particularly for engineering degrees which are regulated by law. So, for university education that follows the French-European model (university degree habilitates for a professional title or profession), the student must fulfill a series of competences; and this fulfillment must be assessed by certified staff –a kind of governmental agents. The administrative and legal effects of university education expand those of simply learning: knowledge must be demonstrated and evaluated in practice. In Spain, some branches of engineering follow this model, so the professional activity is regulated, and its access is also specified and controlled.

In the presented context evaluation must meet several requirements:

- Formal education (we define it as any kind of education part of a certified program that produces legal effects, ranging from kindergarten to university), requires validation and verification activities. To produce a legal effect (passing the course) it is necessary to get a proof that the required knowledge and competence have been acquired.

- Evaluation must be normative, as the levels of competence (learning objectives) the student may get should be described in a clear manner, also specifying the different degrees in which the objectives can be covered.
- Evaluation must be precise so it is possible to infer the coverage of these levels of competence by the student from the results of evaluation (examinations, assignments). For this purpose it must also be objective, meaning that no external conditions may affect the results of the evaluation, such as affective bias from staff towards students.
- Evaluation must be secure. This is the main detrimental factor for a greater adoption of e-assessment tools and techniques. Security relates to the authentication of students, non cheating, non plaguing, control of the processes, etc. For this purpose, face-to-face examinations are still a powerful evaluation tool.
- Evaluation must be fair for comparison between students. Even in the engineering university studies we are presenting, and despite the fact that the key point for students in each subject is the pass/no pass decision (all mandatory subjects must be passed to get the degree); each student is given a final mark in each subject. Individual marks or the aggregate results are used for comparison of graduated students by some engineering companies.
- Evaluation must also help in the learning process, helping each student to get knowledge about his/her level of competence and guiding the selection of optional subjects. During the learning period in each subject, availability of in-the-middle, continuous or formative evaluation results helps the student to focus on the issues he/she would require more effort. It is also a motivational agent.
- Finally, the academic and physical conditions in which the evaluation is performed, as regards the evaluation technique, the time for evaluation, the place and space it is performed on, the availability of consulting material, the text of questions, etc, must be handled with care to get the aforementioned goals but at the same time be realistic within the restrictions in staff and costs universities face.

Face-to-face examination must still be part of the process. Nonetheless, evaluation will be more efficient the more continuous it is; besides, it will be more focused the narrower the context of application. In continuous evaluation schemes, a formative approach can be supported. In this situation, processes and technical infrastructure play a fundamental role reducing the cycle execution total time, improving learning through a fast feedback, and adapting learning to students' pace.

Traditional university education has been mostly driven by summative evaluation activities, performed at the end of a long learning time period (year, semester). This is a one-shot process, focused on the legal effects (pass, fail). It has been shown that evaluation and assessment activities have a strong impact in the overall learning process as their main goals are: give students a mark and ranking, help and motivate them by a quick and continual feedback, drive the syllabus development and also to contribute to analyze the teacher performance.

However, we think traditional methods provide poor feedback to students. It has already been empirically demonstrated that at least in ICT (technological disciplines related with communications and computers) teaching knowledge is mainly acquired by means or practical work. The main drivers for student's motivation are learning-by-doing, and the formative role of mistakes [9] [10].

Because of that, in the last years we perceive a movement inside traditional education, evolving from the "one shot process", quite similar to the traditional waterfall software development process, to "continuous evaluation" models. These models perform several iterations in the course time span, including learning and evaluation in each cycle. However, the number of cycles is limited by the complexity of the whole assessment process. The process is composed by many activities, and involves professors, teachers, and university officers. Each step must also be performed with the required security, controlling agents' communication, detecting forgery and copies, as well as storing the documental proof of the evaluation.

Next, a generic process for evaluation is presented. It has been obtained from our experience and the observation of the different examination methods that are followed by the university staff; while the process does not consider evaluation based on the pure observation of the student behavior, other evaluation type of activities, such as the evaluation based on the delivery of homework or project results (in Project Based Learning approaches) could also be accommodated to this model. Figure 1 shows the five activities currently performed in legally binding (paper based) university examinations. There are five tracks, of which third and fourth affect to the quick feedback to the student.

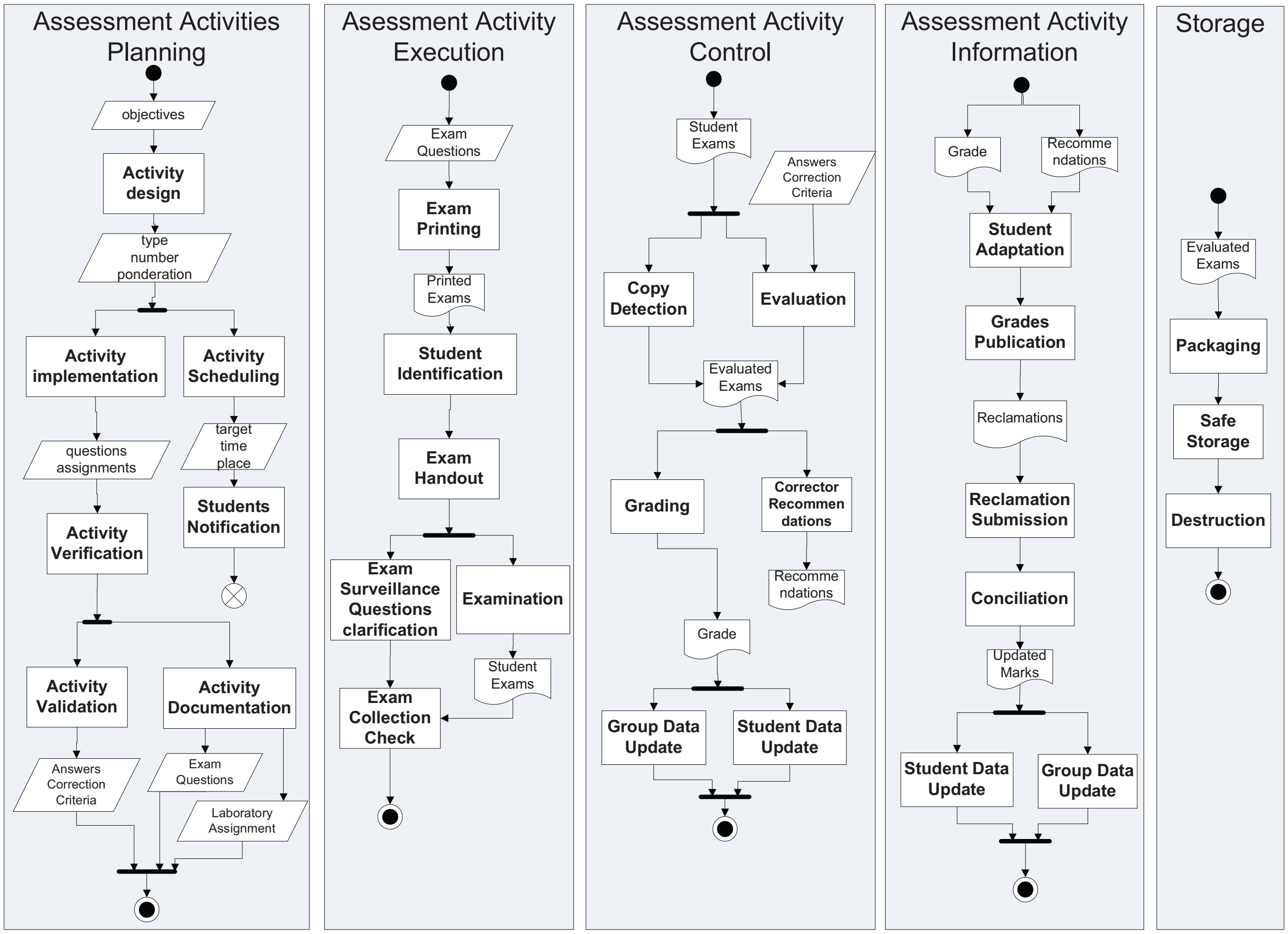

Figure 1 The Assessment Process

1. Development of the evaluation activity. Deals with all the actions required to prepare the examinations ensuring the questions or assignments are accurate and suitable. These activities are performed by the academic staff in a secure mode. They can be made in advance even before the subject period so they do not put an additional burden on academic staff.
2. Execution of the activity. Active participation of each student is required at this point, as he/she performs the examination under objective conditions.
3. Marking which implies evaluation of answers and grading, and constitutes the largest effort to be performed and therefore the highest delay in the feedback to students.
4. Information to students of their performance levels and grades. Also conciliation activities may take place at this point if the student feels in disagreement with the final mark. Review and conciliation activities are regulated by internal norms in our university, but these regulations are only applied for final examinations.
5. Storage of results as any other legally binding document should be safely stored for 5 years.

It is interesting to note that all the activities affect the overall qualities of security, reliability and validity –we call these cross-cutting concerns. It is also worth noticing that so far marking and feedback to students are operations whose effort depends at least linearly to the number of students, hindering the application of methods that imply several examinations, and producing in general poor results as regards the time of feedback.

As it has been mentioned before, these activities are suitable to be automated, but on the other hand a purely computer based approach may not meet the security requirements that legally binding evaluations hold. That is why we approach the problem of evaluation as a mix of purely asynchronous computer based evaluations (in its application to Computer Science I these are programming assignments), with synchronous paper base exams, performed several times during the semester.

The assessment activity development is the first subprocess. Only the academic staff participates in it, and its overall intent is to completely define the assessment activities that will allow measuring the students' fulfillment of the course objectives. The process starts by analyzing these objectives. Depending on the characteristics of the subject, the students' profile, the organizational context and the estimated relevance and criticality of each specific part, the teacher will prepare a high-level design of the subject assessment. By analyzing the objectives, a preliminary definition of the amount of assessment activities, its relative weight to the final mark, and the nature of each type of assessment (written exams – with problems, short and /or long questions - individual or group assignments and laboratory practices) will be performed. Once these activities have been defined, they can be integrated to the overall course planning, scheduling them over the semester, and, if necessary, performing room reservations for its execution. At this point, they can be notified to the students in order to allow a reasonable preparation interval.

In parallel with the organizational tasks, the academic staff will "implement" each activity, defining the specific questions or assignment specifications that will constitute each assessment activity. Once defined, these questions must be reviewed, in order to ensure they are appropriate to the objectives they are intended to assess. This verification should if possible be applied by a different teacher than the creator, in order to provide a broader perspective. Finally, the activity must be properly documented, obtaining the final enunciate of the exam questions, assignment specifications and support material. At the same time, the activity must be validated, in order to define the expected answers and the associated correction criteria. This way, the activities have been completely defined.

The next sub-process is the activity execution by the students, under the teacher surveillance. At this point there are some variations depending on the activity kind. We will describe a written examination, as it is the reference model for any other assessment activity. Prior to the examination time, the teacher must print the physical exams. At the examination room, after verifying the identity of the students, they will be handed out the paper, and the students will start the examination. Over this process, teachers watch over the students and clarify the exam questions. After the scheduled time, the teacher collects the student exams and checks they are formally correct. On an e-Learning context, these activities can also be carried out, as long as the identity of the students is assured.

On a later stage, the teacher proceeds to the marking sub-process, where student answers are evaluated with the reference of the correction criteria, detecting potentially copied answers from different students. Once the evaluation is complete, the academic staff will obtain two results: first, if it is possible to define recommendations to the student, based on the wrong answers and the nature of its mistakes. Second, marks must be obtained from the correctness of the questions. With that information, both individual student data and group data will be updated by the teacher.

Once the marks have been assigned, the teacher will adapt the grade and the specific recommendations to the student, in order to improve the quality of the provided feedback. Once prepared, the complete information will be published to the students, which will have an open time frame to submit any reclamation they consider appropriate to the notified marks. For each reclamation there will be a conciliation process where the teacher and student will review the exam evaluation, and, if the reclamation is deemed right, will update the student mark. Finally, individual and group data will be updated with the changes from the accepted reclamations.

After the assessment has been completed, it is the teacher's duty to ensure that a proper storage is applied to the student proofs. This way, the student exam answers or assignments (either physical or digital) will be safely stored over a set amount of time (stated by the legal normative) and will be destroyed after that interval has passed.

On the light of our requirements for university evaluation, and the observation and formulation of current evaluation processes, we concluded that: it would be feasible to integrate summative and formative evaluations in our environment, this integration would need for several short cycles of assessment in which the feedback of results to students should be very fast, additionally e-learning technologies would help in supporting automatable tasks as much as possible. We performed some experiments in order to check these hypotheses.

IV. Experiments

We have applied the principles of frequent and rapid feedback to students through continuous, formative assessment to a particular subject from the Telecommunications engineering Master degree offered at UPM (which holds learning topics from Electrical Engineering and Computer Science). The specific subject where the experimental techniques were applied is "Fundamentos de programación", a mandatory part of the first semester of the first course of Telecommunications studies which is very similar to "Computer Science I" in other countries. The subject is allocated 47 hours teaching spread along the semester. The subject neither has formal prerequisites nor depends on other subjects –whereas several subjects in the following courses depend on it. This subject has been chosen for experimentation because it offers specific characteristics that make it suitable for improvements in the evaluation process:

- The subject holds both theoretical (knowledge) and practical (operational) competences. Its learning process requires a proactive and practice-oriented effort from the student. As there are few computer programming subjects in the degree, students must obtain a minimum level of proficiency so they can apply programming concepts in later subjects with no more formal learning, despite it is in the first course. Operational contents require a higher level of interaction between student and teacher than pure cognitive contents.
- It builds design competences; students must be able to analyze computer programs, but they must also be able to design or create small programs. This is the first real experience in engineering they get, which requires the student to create his/her personal problem solving process.
- It is offered to freshmen students; so the typical problems of retention of students, wrong selection of studies, adaptation of their study mechanism, and anxiety appear among them. The subject must cope with those factors offering additional motivation as being in the very first semester most of the subjects are on basic (non applied) disciplines such as Mathematics or Physics.

For several years the academic staff has been adjusting both the amount of lessons and its sequence, organizing the subject following an "objects first" approach [11]. Table 1 specifies the topics dealt with, the order in which they are presented, and the time (in minutes) allocated to each of them for the lectures. In this table, the time allocated for the introduction and basic definitions may seem controversial as these definitions do not provide operational capabilities, but they are intended to serve as a "training time", allowing students to get a feeling on the subject –it is the very first semester in the university-.

TABLE 1 SUBJECT LECTURES TIME ALLOCATION

Lesson	Contents	Time(min)
1	Introduction: basic definitions	240
2	Simple classes, objects, references	240
3	Primitive types, operations, arrays	360
4	Methods in classes	240
5	Sentences and simple algorithms	300
6	Classes	240
7	Inheritance and interfaces	360
8	Collections (simple data types)	240

Another key factor which impacts the course organization is the large number of students, ranging from 350 to 500, split into 3 to 5 separate groups. This presents practical difficulties in order to organize the contents of the subject, perform teaching, and include the proper evaluation mechanisms. With these factors in mind the teaching staff agreed to follow a hybrid approach for the summative assessment, shared by all the groups. This way, a quarter of the final mark was assessed from the results of continuous evaluation (performed independently at each group), with the remaining 75% being determined by the final exam, common to every group. This ensured the formality of the process.

In the first semester of course 2007-2008 the first experiment on evaluation improvement was performed. In order to check our hypotheses, we made an effort to apply a large number of assessment cycles over the teaching period, and provide the feedback to students from each of them in a short period (less than 48 hours). This way, we performed a total of 12 assessment activities over 15 weeks (almost one evaluation a week), switching between programming assignments (that could be submitted through the Web) and written exams with short questions (which were performed in the university rooms following the evaluation process presented in Figure 1). The specific contents for each test were very limited, whereas the degree of difficulty was growing incrementally. For all the cases we published the reports before 48 hours from the evaluation.

At the end of the four-month course we validated our approach with the students by means of surveys and by checking marking results against the students from the remaining groups, which were not involved in the experiment. As the marking for each student was primarily determined by the final exam, common to all of the groups, the comparison of the results allows checking the usefulness of this approach to continuous evaluation. The analyzed group had 97 students, whereas the remaining four containing 328 (group composition being assigned at random). Marking results comparison shows that the pass rate was 5% better than the average overall mark, with the absolute grades improving an 8%.

On top of the raw results, further reflection was done over the experience, including the results of the student survey performed at the end of the semester. While the experience was overall positive, there was room for improvement over the implementation. Student feedback informed that the amount of continuous work felt very pressing, and was not directly tied to the final qualifications. In addition to that, it was not only costly for the teacher but also in our impression detracted time for explanation because of allocating so much time to pure evaluation. We believe that the number of continuous assessment cycles was excessive hence hampering the usefulness of this approach, and experiencing diminishing returns when compared with the required effort. These factors guided the evolution of the process for the second experiment.

In the second year of application (first semester of the course 2008-2009) the number of students in the control group was slightly smaller (89), but the same number of groups (5) remained. Based on the previous conclusions, when planning this new execution of the experiment we opted for reducing by 25% the number of continuous assessment activities (from 12 to 9). Table 2 summarizes the assessment activities carried out over this experiment, including information about the weight these activities had on the final grade, the kind of activity (written-programming lab), and the examination contents. In addition to the assessment definition, estimated effort for the execution, preparation and correction-notification time, are presented (in minutes). As it was shown in Figure 1, the preparation time is the time spent by the staff preparing the evaluation and correctors; execution time is the time actually taken by the students in performing the evaluation activity; and correction and publication includes the time to scan and upload written examinations, and for practical assignments the time spent by professors in building and publishing the listings, as well as performing manual inspection of the solutions given by students that did not perform correctly by the automated evaluation system (in these kinds of activities, time spent on erroneous answers turns to be the dominant factor).

TABLE 2 ASESSMENT ACTIVITIES FOR THE SECOND EXPERIMENT

Activity	Week	Weight	Contents	Execution time	Preparation time	Marking time
Exam 1	6	0.25	Short questions: objects, references, expressions, arrays	30	30	240
Lab 1	7	0.18	Simple classes, basic types, operations	60	30	240
Exam 2	9	0.85	Short questions: Methods, classes	45	30	240
Lab 2	10	0.18	Sentences, simple algorithms	120	30	240
Lab 3	11	0.18	Arrays	120	30	360
Exam 3	12	0.25	Regular exercises: classes, interfaces, arrays, sentences	60	30	240
Lab 4	13	0.18	Interfaces, inheritance	180	30	360
Exam 4	14	0.25	Question marks, regular exercises: interfaces, collections(data structures), algorithms	60	30	240
Lab 5 (opt)	15	0.18	Design	240	30	240
Final exam	16	7.5	Full contents	120	360	360
Total		10.0		915+120	270+360	2400+ 360

After applying the same validation in this second iteration we noticed an improvement in the results, which are shown at Table 3. Each column lists the statistics from one of the groups, with A being the subject of the experiment. For each of them group size, average mark and percentage of students passing the course is shown. It can be seen how both the average mark (over 10.0) and especially the pass rate (with 5.0 being the threshold) were significantly improved over the rest of the groups as well as the increased difference when compared to the previous experiment.

TABLE 3 RESULTS FROM THE SECOND EXPERIMENT

GROUP	**A**	B	C	D	E
SUBMITTED	**89**	58	47	49	67
AVG MARK	**6.06**	5.53	4.98	5.68	5.65
PASS/SUBMIT	**74**	47	53	49	60

V. Discussion: the XL method

The presented experiments show the results of applying a set of improvements to traditional evaluation activities which we propose to name “eXtreme Learning” (XL), in analogy to the software development methodology eXtreme Programming [12]. We have found this name used by some UK pedagogic communities [13]. It is also a commercial name that offers services to K12 (pre university) students and organizations. In both usages of the term, it seems to be oriented to the primary and secondary school context. They move the principles and values of XP (eXtreme Programming) to the domain of learning and teaching, but so far they seem to be focused on the first value of XP: communication. For us, XL is a wider method, consisting primarily on the adoption of multiple fine granularity learning cycles in university education. It serves students to control their learning trajectories, providing incremental, fast feedback, integrating summative and formative evaluation.

From the results of its two initial applications we have obtained a set of conclusions which we believe can be extended to other implementations of this approach.

The first key aspect for a successful application is to find the right level of granularity for the activities. There must be a sufficient number of them, in order to provide a focused and frequent feedback to the students. On the other hand, a too large number of tests can lessen the effectiveness of the process, as students can feel overwhelmed by the load of examinations, the time for introducing the new concepts is reduced in concordance, as well as imposing unnecessary load to the teaching staff.

Applying this technique does not only affect the design of the assessment activities, but also influences the course planning. Subject contents must be structured in a sequential development, with each new concept building only over the previous ones. Course contents should be well defined and individually testable. The combination of these factors, will allow focusing only on the tested concept in each of the assessment activities, improving the quality of the feedback provided to students.

As regards the design of the evaluation activities, there are two factors which should be taken into account. Continuous evaluation activities should assess the different types of competences to be obtained from the subject (base knowledge, skills, design capabilities...). In addition to that, it is advisable to select types of activities which can be efficiently evaluated (e.g. short answers / questionnaires instead of long problems), in order to enable a quick feedback process. From the data received by the surveys, we believe that less than 48h is a good threshold value to optimize the usefulness of the provided feedback.

Clearly, from the previous point it can be concluded that e-assessment tools are a great fit to this approach, as they help reduce the required effort for marking, although as it was mentioned before, they do not completely remove the need for manual checking. In addition to that, the security and legal concerns impede to adopt them as the only mechanism, so face to face examination must still be the predominant summative assessment technique.

Finally, we will briefly discuss the relationship between the specific characteristics of the course subject to the experiments and the XL approach.

As regards the suitability for freshmen students, we believe the formative assessment capabilities of this approach can be critical to help them have a smoother transition from their previous learning habits to the steep requirements of the university education. This is not as critical for students from higher courses, as they have already developed the required learning skills.

Another important factor related to these experiments is the high number of students per class, which did not allow providing personalized feedback and learning paths for specific students. However, as rapid feedback informs the students on their continuous progress, it does enable them to take a proactive role where, after looking at the results of his personal progress she/he can request individual lessons (tutorial) to the academic staff. Regarding group size it must also be mentioned that the required effort from the teacher increases linearly with the number of students (and is multiplied by the number of cycles), so it can turn out to be very costly in the presented context.

VI. Conclusions

Over this article we have presented the XL method, applying the eXtreme Learning approach to a traditional university context. Bare bones, our interpretation relies on the execution of lots of assessment tests (both written examinations and practical exercises), corrected and marked quickly, so the student can get a fast feedback on his/her learning process.

Before applying this technique to our context of work we have first analyzed how the domain-specific requirements impact the assessment process. This way, both the formal and security constraints of engineering degree education and the challenges of adapting the subject to freshmen students have been identified. In addition to that, the general assessment process has been described, with an emphasis on the potential techniques for minimizing the complete time required for its execution, which is the only way to provide rapid and frequent feedback to students.

We have defined and implemented this approach for two consecutive years to a first year subject from the telecommunications engineering degree, with several improvements for the later iteration. In our experiments we have found that this fast feedback improves students’ motivation, enhances the quality of learning and reinforces the active role of students in learning.

However, it must be noted that there are several factors which have to be considered before applying this approach to other contexts. First of all, on a traditional university context, the method cannot substitute, but must complement instead the traditional, legal evaluation methods. In addition to the organizational context, it is vital to find the right degree of granularity for the evaluation, and ensure the distribution of course contents allows applying highly focused low-coupled tests.

As future work we plan to increase the role of e-assessment tools in the process. From our experience the availability of an

IT infrastructure that eases the correction, communication and publication activities can substantially reduce the teacher effort, greatly increasing the applicability of this technique. In addition to that, we also plan to improve the quality of the feedback generated by the automated correction system for non-correct submissions, in order to provide personalized feedback to the students.

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Mixed e-Assessment: an application of the student-generated question technique

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Abstract— **This paper presents the experiment of a mixed summative-formative evaluation in an asynchronous distance higher education context. In the experiment, performed in the distance course of Total Quality Management, Industrial Engineering, University of Guadalajara (Mexico), students are guided to formultate questions on specific topics. Student-generated questions are evaluated through an ad-hoc quantitative tool, specifically designed for the purpose: the four-criterion Observation Matrix. The experiment shows: (1) that it is possible to improve the Higher Education evaluation process and formalise students' skill in a more thoroughly way than with traditional evaluation; (2) how the student-educator interaction in a distance learning environment can be enriched through the mixed assessment**

Keywords: mixed formative-summative assessment; distance learning; continuous improvement in higher education; quantitative assessment tool

I. Introduction

Student questioning is a strategy to promote higher-order thinking and to improve learning [1]. Koch and Eckstein [2] showed that students who were taught to generate their own questions achieved more learning outcomes than students who used only teacher's questions. In 1992, King [3] found that training students to generate specific questions and then attempt to answer them is more effective than training in other study techniques. Foos et al. [4] showed that generating potential test questions while preparing for an examination is a very effective technique leading to high performance. Besides, students' questions are a precious source of information on the critical issues in a course [5]. Biddulph et al. [6] and Dori and Herscovitz [7] suggest including question generation in the formal evaluation process. This could be reasonably considered one the aspects of the Darwinian evolution of the learning and teaching paradigm.

Recently, Bergman [8] performed a multistage formative assessment experience realised with Ph.D. students, consisting in formulating "good" questions in areas determined by the examiner [8]. Bergman concluded that this reverse-question evaluation model resulted very interesting for it brought to light learners' "hidden" skills and for the different perception of the evaluation conditions it could lead to by reversing the classical role of questioner and answerer.

Inspired by Bergman's research, Ciancimino and Cannella [9] ran a mixed summative-formative assessment pilot experiment at University of Palermo (Italy). The experiment consisted in planning and realising a two-stage examination within the Business Process Modelling course of the MSc in Management Engineering. Students had to generate written questions about topics of the course selected by the educator. These questions were subsequently answered by the lecturer and become the core of formalised class debates among students, mediated by the educator. Unlike in Bergman's experiment, in the pilot test at University of Palermo the examiner utilised an assessment tool specifically designed for the purpose: the Observation Matrix. This Observation Matrix allowed the educator to assess the students' questions on the basis of a list of binary criteria. A value of 1 in case of compliance of the criterion or a value of 0 else has to be assigned to each of the criteria established during the experiment design: pertinence to the assigned topic, terminology used to formulate the question, level of complexity, multidisciplinarity approach. From the comparison of results of the traditional examination and of the reverse-question evaluation model a number of cases presenting an opposite trend was observed. The experience showed that some of the students that achieved a high mark in the classical exam were low-performers in the reverse-question evaluation. As well, other students had an excellent mark in the reverse-question evaluation but were low-ranked in the classical exam. The pilot experiment provided the educator with a significant feedback, useful for a strength/weakness analysis of the course and for a better organisation of the topics in the course.

This paper presents the experiment of a mixed summative-formative evaluation in an asynchronous distance higher education context. In the experiment, run in the distance course of Total Quality Management, Industrial Engineering, University of Guadalajara (Mexico), students are guided to formulate questions on specific topics. Student-generated questions are evaluated through the ad-hoc quantitative tool, specifically designed for the purpose, namely the four-criterion Observation Matrix [9]. To the authors' knowledge, it is reasonable to consider this experiment the first attempt to evaluate student-generated questions through a distance learning platform.

The experiment shows: (1) that it is possible to improve the Higher Education evaluation process and formalise students' skill in a more thoroughly way than with traditional evaluation;

(2) how the student-educator interaction in a distance learning environment can be enriched through the mixed assessment.

II. Design of the experiment

The mixed reverse-question evaluation was developed through a referenced technique for designing and executing examination processes: the Four Processes Architecture [10]. This theoretical framework defines four phases, each of which defines a specific process within the examination, from the learning outcomes selection to the final evaluation of examinees. The phases of Four Process Architecture are summarised in the followings.

(i) Activity Selection: consists in selecting and sequencing tasks to be accomplished by the students. The lecturer of the MSc distance course of Total Quality Management selected three topics from the programme of study: (a) Origins and Evolutions of Quality Management, (b) Statistical Tools for Quality Management, and (c) Total Quality Control. During the six-month course, the students were required to accomplish the routine weekly activities (reports, questionnaires, numerical problems), and monthly verifications. At the same time, each two months the mixed reverse-question model was adopted for the three topics.

(ii) Presentation process: is responsible for presenting the task to the participants. The mixed reverse-question evaluation model was presented to the students during the first month of the course as part of the formal evaluation of the course. Students were required to generate one question for each of the three topics selected in the phase (i) of Almond's framework. On the Moodle platform modality and scheduling of the exam were detailed, including explication of the evaluation criteria and examples. Exemplars of "good" and "bad" questions, chosen so as to illustrate what distinguishes high quality from low [11], were also showed to students, in order to provide a general reference of the level of performance they were required to reach.

(iii) Response processing, has the objective to provide evidence about the participant's current knowledge, skills and abilities. This process was aimed at evaluating the student-generated questions according to the criteria presented in Section 3: pertinence, terminology, level, multidisciplinarity. In this phase the educator recollected the questions and performed a preliminary analysis on their characteristics with reference to the identified criteria. At the end of each mixed reverse-question evaluation session, the educator completed a document in the Moodle distance learning platform for each student with a qualitative evaluation of the questions, including a detailed commentary on their performance and advices on how to improve it. As well, in the same document the educator answered the student's question.

(iv) Summary Scoring: consists in converting the qualitative observations into a numerical value representative of the evaluator's beliefs about the participant's knowledge, skills, and abilities. In this phase the educator filled the Observation Matrix for each student (fig. 1).

OBSERVATION MATRIX				
Student name:				Student ID:
Course:				
Questions	PERTINENCE	TERMINOLOGY	LEVEL	MULTIDISCIPLINARITY
1	___	___	___	___
2	___	___	___	___
3	___	___	___	___

Figure 1: Observation Matrix

The resulting data were gathered in a spreadsheet file and the evaluation of each question was obtained through equation 1. The average value of the assessments of the three questions was the final grade in the mixed reverse-question evaluation.

III. Evaluation Criteria

In the literature, student-generated questions were categorised and assessed differently, but with a shared emphasis on higher-order thinking skills [12]. Dori and Herscovitz [7] created a quantitative method to obtain a single numerical value, indicative of the level of complexity of students' questions. Marbach-Ad and Sokolove [13] developed empirically an eight-level taxonomy to categorise students' questions for increasing order of thinking. Chin et al. [14] classified students' question during laboratory activities in wonderment questions and basic information questions. In Barak and Rafaeli's research [15], quality of question was assessed both by educators and students: students assigned a value within a numerical scale, teachers evaluated on the basis of the cognitive level required to formulate the question, on the basis of a modification of the Bloom's et al. taxonomy of learning domains [16]. Bergman [8] evaluated students' questions through a pass/fail methodology.

In this work, the evaluation of student-generated questions is structured according to a multi-dimensional quantitative method: the PTLM (Pertinence, Terminology, Level, Multidisciplinarity) model. Each question is assessed with the following binary criteria:

(a1) Pertinence: relevancy of the formulated questions to the assigned topic. It is evaluated whether the question has precise and logical connection to the topic.

(a2) Terminology: appropriateness of the words chosen by the student to formulate his questions. Syntax and vocabulary of technical terms used are evaluated.

(a3) Level: extent in approaching the topic. This facet of performance was included to take into account the level of detail of the student's question. It is evaluated whether the question is trivial or if it expresses a significant meaning reflecting the deepening of analysis involved in the reasoning.

(a4) Multidisciplinarity: expansion of the range of subject areas included in the question. It evaluates the ability to connect knowledge from other areas to the topic.

For each dimension the examiner assigned a value 0 if the minimum level is not achieved, 1 if the question satisfies the criterion. The result of the evaluation for each question is a value between 0 and 4, successively normalised to 1 (Equation (1)).

$$C_j = \sum_{i=1}^{4} a_i \bigg/ \sum_{i=1}^{4} i \qquad (1)$$

The final grade for each student in the mixed reverse-question evaluation is computed as the average value of C_j, $j=1\ldots3$.

IV. Results and Discussion

This section is dedicated to present and contrast result from the traditional evaluation and the mixed reverse-question evaluation of the thirty students of the Total Quality course of the MSc in Industrial Engineering at University of Guadalajara (Mexico), academic year 2008.

The first result of the experience was that the degree of interaction between students and educator significantly increased. Moodle sessions increased up to 37% with respect to the previous courses average. Students were enabled to generate questions within a formalized framework, which provided a further stimulus to express their doubts and perplexities. This incentive can be considered particularly significant in a limited interaction context as an asynchronous distance learning environment.

The numerical values resulting from phase (iv) of Almond's framework [10] are reported in Figure 2. Grades of the traditional evaluation and of the reverse-question evaluation are compared. All grades are normalised to 1.

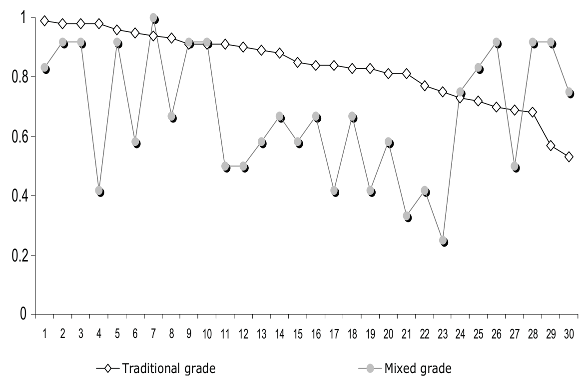

Figure 2: Traditional grade and mixed grade

From Figure 2 it is possible to identify three groups, distinguished by differences in the relative grade on the two evaluations. The first group students (from 1 to 10) performed well both in the traditional and the mixed reverse-question examination, the second group (11-23) performed in the traditional exam better than in the reverse-question, while for the last (24-30) group a better performance in the reverse-question was observed; observation 4, 6, 8 and 27 are exceptions.

In particular, comparing group 2 with group 3, an opposite trend between performance in traditional exam and performance in the mixed reverse-question examination can be noticed. Besides, the grade in the mixed reverse-question examination of students which are low-performers in the traditional one (group 3) is higher in absolute value than the grade in the mixed reverse-question examination of students from group 2.

Figure 3 shows the percentages of accomplishment of the four criteria of the mixed reverse-question evaluation.

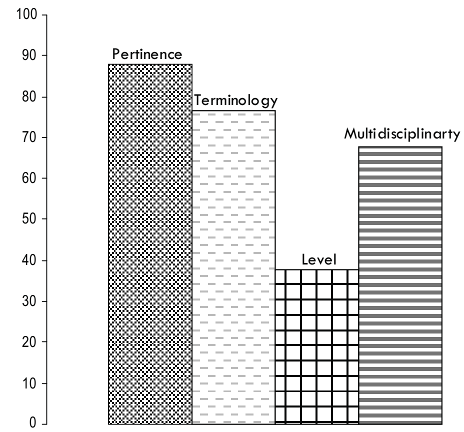

Figure 3: Percentages of accomplishment of the four evaluation criteria

Figure 3 shows that the level criterion was accomplished only by the 38% of questions, the pertinence by 88%, the terminology by 77% and the multidisciplinarity criterion by 68%.

Jointly analysing Figure 2 and Figure 3, a significant difference can be noted between the average grade obtained by students in the traditional examination, 83%, and the percentage of accomplishment of the level criterion. The level criterion is assumed to reflect the deepening of analysis and the understanding of the topic. The relatively low average accomplishment of this criterion could be symptomatic of superficial understanding of the course topics by the majority of students. The difference between traditional tasks and student-generated questioning could be indicative that the learning strategies aimed at succeeding in a traditional examination are not always sufficient when an additional effort is required for creative conceptualisation, which is a fundamental component of problem solving capability. From the comparison between traditional exam and the mixed reverse-question evaluation it is possible to hypothesise that the majority of students involved in the experience has had difficulties in converting their knowledge in capacities and competences.

Results from the experience underline that the mixed reverse-question evaluation method provides the educator with a structured feedback tool, which can release information about students' achievements in terms of learning, abilities and capacities. Furthermore, the comparison between traditional grades and mixed reverse-question evaluation grades are a concrete element for the educator to perform a structured strength/weakness analysis of the course.

From these reflections two main conclusions derive:

(1) Adopting a formative exam and formalising it within a structured framework capable of releasing quantitative information can represent a concrete tool to improve the learning system, as it provides information that is complementary to the classical feedback coming from a traditional exam. The effort for developing, improving and validating innovative tools is a priority for the scientific community. From this perspective, improving the Observation Matrix was reconfirmed as one of the main objectives of the experiment. In this experiment the educator provided a list of suggestions and observations, whose synthesis is presented in Appendix.

(2) The results of the experiment confirm the need for improvement of the higher education system auspicated by the European Community. There is the need to re-think and restructure the student-educator interaction and to enrich the teaching methodologies, in order to balance theoretical knowledge and practical capabilities and competences. Adopting mixed formative-summative evaluation methods can facilitate the conjoint development of the three learning outcomes established by the European Community: knowledge, skills and competences.

V. Conclusions and Future Research

This paper presented the experiment of a mixed summative-formative evaluation in an asynchronous distance higher education context. In the experiment, performed in the distance course of Total Quality Management, Industrial Engineering, University of Guadalajara (Mexico), student-generated questions were assessed through an ad-hoc quantitative tool, specifically designed for the purpose: the four-criterion Observation Matrix. The experience showed: (1) that it is possible to improve the higher education evaluation process and formalise students' skill in a more thoroughly way than with traditional evaluation; (2) how the student-educator interaction can be significantly increased through the mixed reverse-question evaluation method.

The limitations of this study also represent opportunities for future research in the formative-summative assessment field. For example, use of language and writing style could be further elements of student-generated question evaluation, regardless the use of technical terms. Furthermore, as answering the students' doubts resulted more interesting and helpful for teacher and students than mere numerical (summative) evaluation of the criterion fulfilment, this could be formally included in the reverse-question evaluation model. Another point regards the improvement of Observation Matrix. It would be desirable to have intermediate score between 0 and 1. By doing so, the evaluation of fulfilment of criteria could be more informative than the pass/fail scoring.

Aknowledgment

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Session 04E Area 1: Computer Supported Collaborative Learning - Proposals and Methodologies

Experiences in using a MUVE for enhancing motivation in engineering education

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A Student-Centered Collaborative Learning Environment for Developing Communication Skills in Engineering Education

Alonso-Atienza, Felipe; Guerrero-Curieses, Alicia; Requena-Carrión, Jesús; Rodríguez-González, Ana Belén

University Rey Juan Carlos (Spain)

Trends of Use of Technology in Engineering Education

Castro-Gil, Manuel Alonso; Colmenar, Antonio; Martín, Sergio

Spanish University for Distance Education-UNED (Spain)

Ranking Learner Collaboration according to their Interactions

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Experiences in using a MUVE for enhancing motivation in engineering education

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Abstract— **NUCLEO is an ongoing research project that aims at developing a MUVE (Multi-User Virtual Environment) platform for collaborative learning, which uses a role game and a virtual fantasy world to stage a problem-based collaborative learning strategy. The project has four main objectives: (1) to stimulate a change of attitude among students towards studying, forcing them to change their passive listener role to a more active role; (2) to increase students' motivation by adjusting the visual features and the interface of the environment to the peculiarities in the way members of the net generation interact with contents and process them; (3) to help to develop communication skills, teamwork abilities and soft skills in our students, while at the same time they acquire the knowledge and technical abilities included in the subject curriculum; (4) to integrate the platform into an e-learning management system application as a way of centralizing the data management, while at the same time offering the chance to combine it with the use of other instructional strategies that can be applied to wider contexts. This paper introduces the reference framework under which the NUCLEO system has been developed, along with the specific model designed to fulfil the objectives mentioned above.**

Keywords-Computer supportted collaborative learning, Virtual Larning environments, Problem Based Learning.

I. Introduction

Traditional learning strategies are generally based on the revision of contents carefully structured by the teacher and on solving series of exercises organized by themes following an increasing level of difficulty. Also, they usually rely heavily on textual static content with few interactive features. Several analysts [5],[11] sustain the hypothesis that young people today are reluctant to focus their attention on this sort of content format, because of the way the process and interaction with contents has been deeply affected by their everyday exposure to multimedia and ICT devices.

These factors, along with several other related problems, such as, for instance, increasing dropout rates at all education levels, have led the educational community to try new ways of learning, particularly those that seem closer to the aesthetics and the high level of interactivity the net generation seems to prefer, such as educational videogames.

However, this kind of approach doesn't seem to fully satisfy any of the stakeholders in the educational process so far. On the teacher's side, learning with games drags on, is often centred on wrong motivations (i.e. winning instead of acquiring knowledge), and achieving specific learning objectives becomes a difficult task. On the students' side it is generally believed that educational content diminishes the pleasure of playing to a considerable extent.

Moreover, other than a few exceptions [8], most of the game based learning approaches have been developed with no regard to the tools for managing the whole educational process that presently have the highest level of acceptance among educational institutions: Learning Management Systems (LMS). We consider this a big mistake. Not only because it would be recommendable to pay off the huge investments made until now, or to take advantage of the advancements concerning the standardization process of many of LMS features (contents, run time environments, sequencing, learning strategy design, profile management, exams), but also because LMS are wide scope applications that comprehensively manage the whole learning process (in many aspects unreachable by necessarily more limited applications such as videogames). The fact that their interfaces and interaction mechanisms not longer seem to be fully attractive to the net generation does not invalidate their functionality. From our point of view, the goal is rather to complement their functionality with richer modes of interaction, while taking advantage of the developments and the advances already achieved.

The NUCLEO e-learning project has been under development and testing during the last three years in actual academic learning courses in the Electrical Engineering Faculty at the University Complutense of Madrid. It contributes to the research of new ways of learning in the following aspects:

- It seeks to promote a change of attitude among young learners in such a way that they have to abandon the passive role they play throughout their training.
- We look for an effective learning process targeted to achieving specific curricular objectives, and designed to be attractive to the current generation, as well as

increasing motivation by applying the formats and interaction modes the "digital natives'" prefer, and reaching a compromise between learning and amusement which reasonably satisfies both parts implied (teachers and students).

- It promotes the development of team work, leadership abilities, and communication skills in the students. Traditional learning strategies are mainly focused on developing students' technical abilities and knowledge acquisition, while today's job market demands a wider range of personal abilities, among which those related with handling work coordination within a team are specially valuable.
- It achieves integration into an LMS, on the idea that the tools developed under the proposed reference framework can be complementarily used with other learning strategies, designed and managed through an LMS. Therefore we obtain a twofold benefit: we increase cost effectiveness, on one side, and we increase the pedagogical range and the target audience of the application on the other side.

The rest of the paper is structured as follows. In Section 2 we introduce the reference framework in which the NUCLEO system was developed. This reference framework is conceived as the baseline model for developing e-learning teaching approaches targeted to complying with the learning needs of a particular population context in a particular situation, and for integrating such approaches in an LMS. In Section 3 we introduce the specific framework developed for the NUCLEO e-learning system, which was benchmarked at the experimental level with extraordinarily promising results relating to the first three objectives mentioned above. Finally in Section 4 the experimental results obtained so far are briefly presented together with some conclusions as the outline for our future work.

II. A REFERENCE FRAMEWORK

The reference framework we propose in this section identifies the main components and interfaces for the development of e-learning solutions targeted to a specific situation, while allowing its integration with an LMS. We depart from the hypothesis that there are no absolute models for teaching and learning, but instead one application will work better or worse at reaching certain learning objectives depending on the targeted audience (social context). Therefore we consider it important to hew closely to a comprehensive system that allows for managing different strategies and solutions, and provides a centralized database in order to maintain continuous learning processes.

At its highest level of abstraction, the framework is organized into five components (see Figure 1):

- *Underlying pedagogical stream*. Its choice will condition the remaining layers, since it is related to the concept itself or the nature of learning, which is to say:

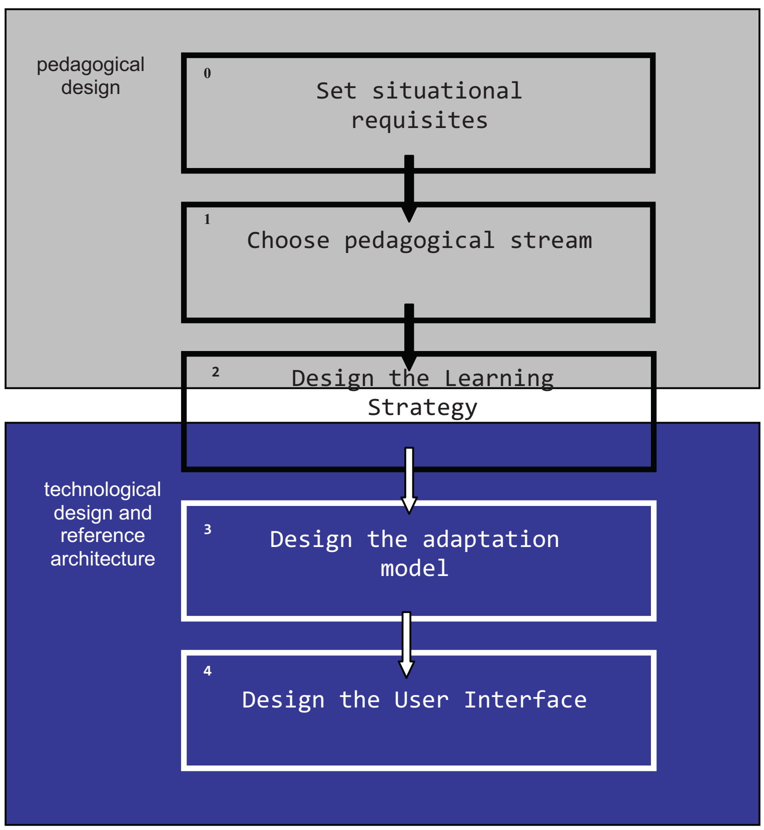

Figure 1. Reference framework used for designing NUCLEO system

what the meaning of learning is and how to achieve it according to a series of generic principles.

- *Learning strategy*. A learning strategy is a particular specification about how to undertake a learning process. It is in the strategy where all the elements in the learning process are defined as well as the way in which they are executed. The definition of a strategy is conditioned by the underlying teaching approach as well as by the definition of the adaptation processes (which in some cases affects all or a part of the elements in the strategy).
- *Adaptation*. Adaptation is the learning system ability to customize certain aspects of the learning process in terms of certain student characteristics (including previous knowledge, preferences, limitations, personality, learning styles…), founded on a series of predetermined rules. The pedagogical stream has influence over the adaptation layer's existence (since from cognitivism onwards all streams consider that each individual reacts in a different way when he/she is placed in a learning context), and the learning strategy determines what, how and the terms of what the adaptation must achieve. In turn, the adaptation process itself also has influence over the strategy, determining which specific aspects must be modified. Therefore these two layers are interrelated.
- *User interface*. The user interface for an e-learning system is the way of communication and interaction between the learning strategy layer and the student. In other words, the interface is the main element for the staging of the learning strategy.
- *Interface with the LMS*. The interface with the learning management system acts as a mechanism for exchanging information between the situational application and the LMS. The situational application is specifically conceived for a particular context. The LMS is in charge of managing all the processes and data implied in a comprehensive context supporting the continuous learning.

III. USING THE REFERENCE FRAMEWORK FOR DESIGNING THE NUCLEO SYSTEM

This section explains the specific model designed for the NUCLEO system, using the reference framework depicted in Section 2, regarding what we have defined as "situational requirements", which are as follows:

- *To whom is the tool targeted*? At a first stage of the project development, the tool is targeted to the current university population, which belongs to the so called "net generation". The students that belong to the current generation are used to accessing information in a discontinuous way, jumping from one subject to another, and they would rather use multimedia digital formats than textual printed ones; they prefer interactive hypermedia contents to static ones; multitask working is easy for them, and they are used to being permanently connected with their peers (e.g., through instant messenger tools). They also feel uncomfortable if they do not obtain quick feedback and immediate responses.
- *What is the application context?* Our tool is mainly targeted to higher education in strongly practical content domains.
- *What are the learning process objectives?* We pursue three main objectives: driving students toward the development of skills for team-work, communication (soft skills), and problem-solving; promoting a change of attitude among students that turns them into active learners; and increasing motivation, while trying to attain learning specific goals included in the subject curriculum.

A. Underlying Pedagogic Rationale

Taking into account our situational requirements (namely, turning students into active actors concerned with their own learning, and promoting the development of skills for real problem solving in complex situations, along with soft skills), we have opted for an approach strongly rooted in the socio-constructivist pedagogic stream [12], [16]. Specifically, we use a problem-based collaborative learning system, or PBL ("Problem Based Learning"), whose original scheme was developed more than thirty years ago by Neufeld and Barrows [9]. This sort of strategy has been often implemented in collaborative e-learning environments or CSCL environments (Computer Supported Collaborative Learning or sometimes Computer Supported Cooperative Learning), even though tools included in CSCL cover a wider set of applications that can be sustained by different pedagogical approaches [13].

While in traditional environments tutors are responsible for providing and organizing the information and providing students with contents in a structured way, in PBL environments the students acquire knowledge during the process of solving complex collaborative problems. Therefore, the tutor role changes from being the sage on the stage to being a guide in the process of finding a solution. He provides hints and encourages the students to seek the information and knowledge sources. In spite of the unquestionable pedagogical values socio-constructivism in general and PBL in particular provides [6], it is not easy to implement PBL, especially in a non face-to-face setting. Three of the main reasons are:

- The tutor must do a comprehensive follow-up of students, leading them and giving them clues and feedback, tasks that considerably increase his/her teaching load, since he/she is forced to conduct and supervise the steps of many small groups.
- The effectiveness of a collaborative learning process is highly related to group dynamics. The success of the educational experience relies deeply on the capacity to handle effective coordination among the members of the work group. In extreme cases, being part of an ineffective team, whose members do not establish suitable collaborative dynamics, can be frustrating and end in withdrawal [1].
- The creation of social bonds among participants seems to be the one of the keys to establishing effective collaborative dynamics. Nevertheless, it is not enough

to form the groups and to provide the students with some support for communication in order to develop the appropriate dynamics [4].

In the NUCLEO system the remaining situational layers (the learning strategy, the adaptation model and the user interface), are designed with the aim of establishing an effective model of collaboration that will lead to a more effective learning process, while at the same time reducing the tutor´s teaching load.

B. Learning Strategy

As already mentioned, the learning strategy used in NUCLEO follows the classical scheme for PBL approaches, according to which students must collaborate in small groups to solve complex, ill-structured, real world problems. The difference is that in NUCLEO the real world is a "fantastic" one. Problems are embedded in a game narrative, and solving them is part of the game. Instead of trying to disguise the educational aspect inside the game, as is most commonly done in some game based learning approaches, we have turned the whole learning setting into a game, on the idea that playing and solving problems share many features [14].

The baseline metaphor leads the students to a fantasy world in which they play the role of warriors trained to face a threat against their civilization. During the training, organized in teams, they will have to confront "assigments" simulating real danger situations, in order to reach the grade of "Paladins" for which they compete individually and in groups, with the aim of obtaining the best score (the idea was inspired by the book "Ender´s Game" by Orson Scott Card). Once this setting is introduced, we proceed to test the students by placing them in an active role, so that they are considered candidate warriors for the Paladins corps, and it is on their shoulders that the survival of the civilization lies.

As in any classical PBL method, groups have to solve a practical case. In NUCLEO assignments represent practical cases in the domain of knowledge that follow the narrative of the baseline metaphor. Hence, they must be solved by a team in which concrete functions and responsibilities are assigned to each individual by means of his/her role (teams as well as roles are determined by the adaptation model).

C. Adaptation

The adaptation model in NUCLEO aims at improving the team's efficiency, which produces a comprehensive improvement in the learning process and a lesser teaching load for the tutor. With this objective in mind, we are using two combined strategies:

- *Formation of heterogeneous teams*. The aim is to avoid the grouping of the students with the most effective learning strategies together, while leaving the less effective ones on the same team, which would bring about the subsequent impoverishment of the whole learning process [10]. We use the framework proposed by Vermunt to distinguish the students with the most effective learning strategies [16] from the ones with weaker strategies, in order to place at least one strong student in each group, since one of the principles implicitly assumed in collaborative learning is that students learn from each other.
- *Assignment of functional roles*. The roles are assigned to each student by means of his/her profile according to Vermunt's model, which is initialized and maintained through a user-modelling process.

The adaptation cycle follows the same cycle the learning strategy does: in every mission teams are reconfigured, and roles are reassigned. It is performed directly in the Moodle LMS. We have developed an automatic grouping manager tool

Figure 2. Air perspective of Dragon Island.

that it is installed as a plug-in in the LMS.

The group manager takes the result of the Vermunt Inventory of Learning Styles as

D. User Interface

Many studies have shown that the user interface is a key feature to attract the students' attention and interest [7]. An attractive interface may encourage students, while increasing effectiveness of learning. Besides, it may contribute to developing students' ability to perceive, organize, integrate and remember information. On the contrary, an unsuitable poorly designed interface may have an influence in lowering student's interest and even in withdrawal. As mentioned above, the kind of interface chosen for NUCLEO, as well as its design, is oriented to bringing the learning environment closer to the net generation's preferences and peculiarities. But that is not our only objective. We also pursue the student's identification with his/her avatar, the immersion atmosphere and its positive influence in establishing social bonds to improve the collaboration scheme and foster the sense of belonging to a community of practice. And finally, our third objective is to provide the setting and narrative for turning the typical PBL setting into a game, thus contributing to the student's immersion in the story.

NUCLEO also provides 3D settings to stage the two existing levels of social interaction: collaboration among members of the same group occurs inside a ship, while intragroup interaction among all participants in the course takes place in the Dragon Island, a space station with different areas linked to different educational functionalities (see Figure 2).

In addition to this, to foster the sense of competition, student avatars acquire differential features in terms of their intellectual achievements, and individual and team scores are public, as it has been observed that one of the most powerful incentives for the players in MMORPG (Massive Multiplayer Online Role Playing Games) environments is the social recognition by the community of users [2].

E. Interface with LMS: a bridge between MUVES and LMS

The use of digital games and Multi-User Virtual Environments (MUVEs) as educational tools has drawn significant attention [3]. Digital games engage users with challenges that take place inside immersive narratives using realistic artificial scenarios, where students can formulate hypothesis and test them in the virtual world. Hence digital games are an ideal channel to promote relevant educational aspects such as problem-solving skills or analysis and reflection.

Nevertheless, as recent research reveals [15] most of the educational gaming approaches present a lack of balance between educational value and fun, which is the game essence.

Also, the use of digital games and MUVEs has some drawbacks that have not been totally addressed yet. For instance, digital games and MUVEs are rarely fully integrated

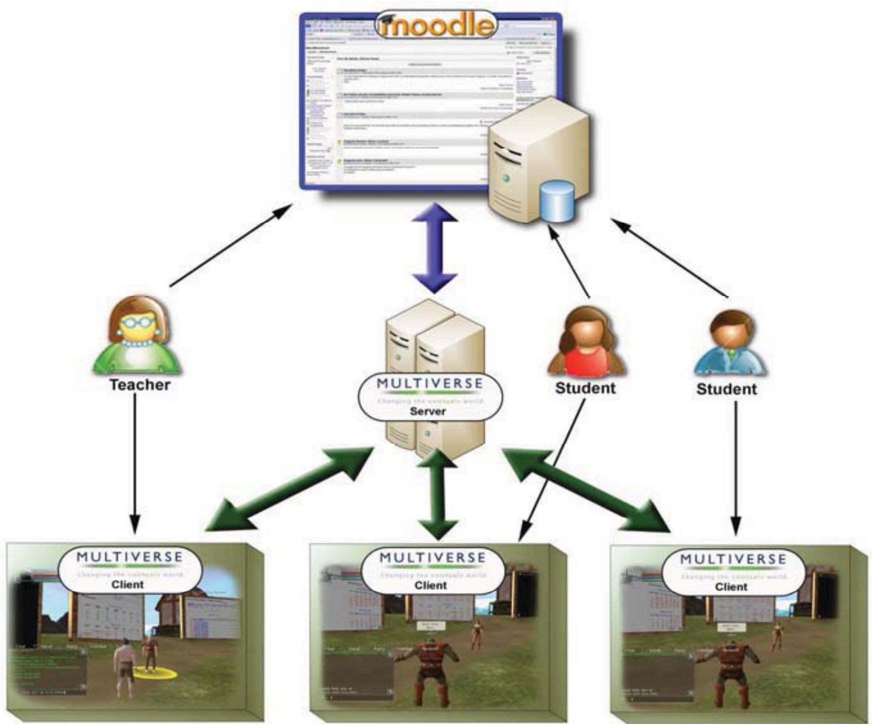

Figure 3. Reference architecture for the NUCLEO framework

in the educational infrastructure and behave as "black boxes". Thus it is impossible to get any instructionally relevant information about the course of the game-based learning experience, such as students' performance for assessment or keep a persistent student historical record.

These issues could be addressed by taking advantage of the already deployed e-learning infrastructure. Many educational organizations are using modern LMS not only for distance learning but also as a complement for traditional lectures (an educational trend usually known as blended learning or b-learning). Those LMS (e.g. Moodle, Blackboard-WebCT, Sakai, etc.) are not only content repositories, but rich web-based systems, that provide instructors with tools to track and evaluate the performance of the students, keep a record of each student or to promote communication and collaboration between students (i.e. collaborative learning). Thus a synergy between educational gaming and e-learning could bring together the benefits of both worlds.

This is precisely one of the key issues where the NUCLEO project aims to contribute. NUCLEO is an instructional framework that integrates a 3D MUVE with an LMS (Figure 3 shows the reference architecture). NUCLEO is conceived to be used as a plug-in application over an LMS, therefore, services, tools and data are managed in a centralized way at the same time that simplifies its integration in the educational infrastructure.

IV. BRIEFING OF EXPERIMENTAL RESULTS AND CONCLUSIONS

The significant hypotheses on which the framework proposed in Sections 3 and 4 is based have been benchmarked at the experimental level during the 2007-2008 and 2008-2009 academic years in three different settings of higher education. So far, we have obtained rather promising results because dropout rates have dramatically lowered compared to the previous years in which a traditional pedagogical strategy has been applied (see Figure 4 and Table 1).

STATISTICAL DATA FOR DROPOUT RATES FOR THE 2005-09 PERIOD.

Academic year	Pedagogical approach	Students enrolled	Students attending the exam	Dropout rate (%)
2005-06	Traditional	115	43	62.61
2006-07	Traditional	110	33	70
2007-08	Traditional	38	13	65.8
	NUCLEO (Mundo Nucleo)	22	20	9.09
2008-09	NUCLEO (Mare Monstrum)	54	45	16

In addition, in 2008-09 students filled a satisfaction questionnaire to collect their opinion over different issues related to the system, including what was the perceived effect of using a virtual world as user interface as a motivating factor. The question was: "In your opinion, has the 3D virtual world GUI affected your motivation?". 51% of the students thought the MUVE was a positive motivating factor, while 41% thought it caused them a delay in their learning duties and was unnecessary. The rest considered the virtual environment as neutral in terms of motivation.

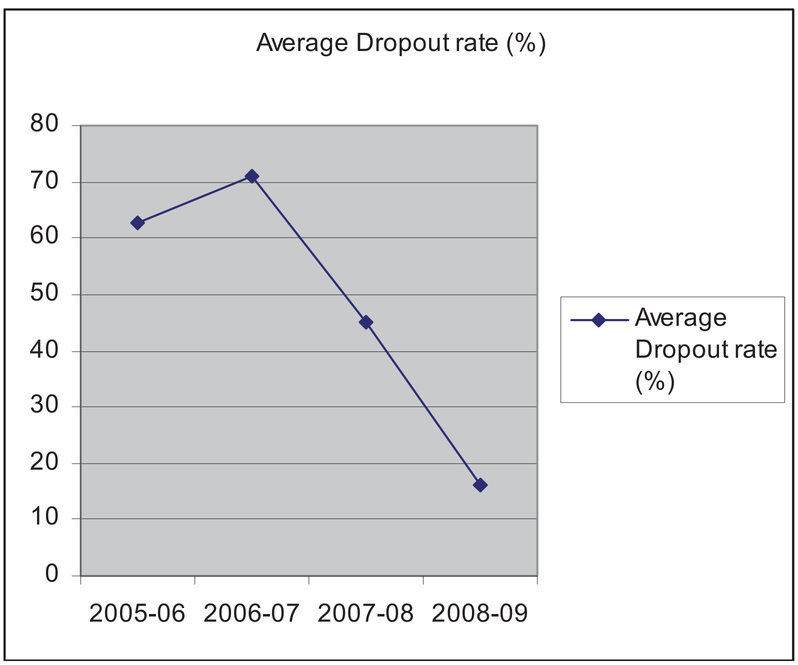

Figure 4. Evolution of the dropout rates through 2005-2009 period.

Even though this evaluation is just a starting point, and more practical research has to be performed in order to establish final conclusions, taking as a base the results obtained in our experiments, we can extract the following conclusion: Fantasy and gaming are powerful motivators, but representing them in immersive 3D multi user interface, with powerful graphics, does not seem to be as important as the gaming or the learning strategies themselves.

During the actual academic year more research is being performed in order to get a more concluding result. Potentially, we consider that this sort of environments would increase its benefifts when teaching less structured subjects, in which it is much more difficult to formalize knowledge and therefore to acquire the skills pursued (e.g. in working-team management and leadership skills). We think it opens a wide field of uses for business training.

Next steps in the project are to obtain a more complete MUVE, easier to install, with improved teacher support and to extend its usability for other knowledge domains different from programming courses.

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A Student-Centered Collaborative Learning Environment for Developing Communication Skills in Engineering Education

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Abstract— **Communication skills development is one of the main goals of engineering education. We propose an integrated student-centered collaborative learning environment for developing communication skills, using project-based learning methods and peer assessment. In our learning environment, projects are assigned to small groups of students under teacher supervision, documented in a wiki-editing tool and presented during a public poster session. By combining wiki entries and poster presentations, we intend to facilitate students (1) to gain access to the project of their peers and share their results, (2) to analyze and comment critically the project of their peers and provide them with feedback, and (3) to enhance their writing and oral skills. Previous experiences encourage us to promote this integrated learning environment. Wiki environments allowed students to improve the quality of their projects and to develop a critical attitude towards their projects and the projects of their peers. The poster session was found to be more dynamic than traditional oral presentations. Students got engaged in a more open and critical manner with the project of their peers, and students presenting their project had the chance to improve the quality of their presentation on the fly, by presenting their work several times in the duration of the session. In future courses, we will implement a learning environment that combines both wiki-based and poster session approaches. We expect that the implementation of both approaches will help to develop the communication skills of engineering students.**

Keywords- communication skills; collaborative learning; wiki; poster session; project based learning.

I. INTRODUCTION

One of the main goals of engineering education and higher education in general, is to enhance students' communication skills, which comprise abilities such as reflection, critical thinking and analyzing, writing and oral skills, and teamwork. Engineering curricula sometimes include courses that are specifically devoted to developing communication skills. Another common approach is to develop them as transferable skills and create in any course, irrespective of its contents, a learning environment that promotes reflection, criticism, analysis and bidirectional communication between the teacher and the students, and among students themselves.

A successful way of enhancing communication skills is by organizing students in groups, which are assigned specific tasks or projects. Group projects are being increasingly used in higher education in general, not only because they facilitate the intellectual and social dimensions of education, but because they mirror industrial approaches to problem solving [1]. Group projects promote discussion between the members of the group, i.e. intra-group communication. In addition, presenting projects in oral sessions further enhances communication skills at inter-group level and serves as a basis to disseminate students' work among their peers. Finally, group project approaches, in both intra-group and inter-group dimensions, open up the possibility of peer assessment, which constitutes an interesting experience for critical thinking and analyzing [1]. Nevertheless, in certain cases as for example, when there are a large number of students, achieving agile dynamics in the classroom when using group project approaches can be difficult. In this scenario, disseminating the work of each group and collecting feedback from their peers can be problematic, and oral presentations can be lengthy and passive.

Communication skills development can benefit from the use of web-based collaborative environments. The emergence and rapid proliferation of web-based collaborative environments, notably the Wikipedia [2], has revolutionized the traditional models of understanding the nature of knowledge itself, and has promoted the creation of global knowledge communities. As an inevitable consequence of this knowledge revolution, web-based collaborative environments have entered the classroom too, mainly in the form of a wiki. A wiki is simply an on-line editing tool that allows its users to create, comment and navigate a collection of documents, which are also known as entries. Web-based collaborative environments have been implemented for different purposes in the classroom. Some authors have emphasized the use of wikis and similar tools as repositories of shared knowledge [3] [4]. Taking the constructivist paradigm as a basis, other authors have highlighted the opportunities that wiki environments offer in education [5]. Reflective learning and critical thinking can also benefit from wikis [6] [7]. Finally, wikis allow coordinating group projects on a global scale [8].

In this paper we propose an integrated student-centered collaborative learning environment aiming at enhancing communication skills. Specifically, this environment promotes the development of fundamental abilities such as writing and oral skills, critical thinking, analyzing and teamwork by using project-based approaches, wiki-based environments, poster presentations and peer assessment. The rest of the paper is organized as follow. In Section II we describe the design of our integrated learning environment. In Section III, we present the outcomes of previous teaching experiences that included some of the fundamental components of our proposal. Finally, Section IV conveys our conclusions.

II. Learning Environment

Communication skills comprise a collection of abilities, which include reflection, critical thinking and analyzing, writing and oral skills, and teamwork. We propose a learning environment to enhance communication skills that can be implemented in an engineering course, irrespective of its contents. We form our approach based on constructivism. According to this paradigm, the best way that people can learn is by means of constructing knowledge itself. The main features of constructivism are the following [9]:

- Knowledge is constructed through reflective abstraction.
- Cognitive structures facilitate learning.
- Cognitive structures are in continuous development.

Taking constructivism as our starting learning theory together with student-centered teaching approaches, the basic ingredients that form our learning environment are two, namely project-based methodologies and peer assessment. By organizing students in project groups we seek to facilitate students to construct knowledge, to engage students with the subject matter of the course, to promote discussion among peers in the same project group, i.e. to promote intra-group communication, and to stimulate teamwork. Peer assessment favors reflection, critical thinking and analyzing, and peer communication.

In order to create a learning environment that integrates all these elements coherently, we propose to implement two strategies to promote communication, documentation and dissemination of knowledge in both the writing and oral dimensions. The strategy for enhancing writing skills uses a wed-based collaborative tool, namely the wiki. The strategy for enhancing oral skills consists of a poster session during which students present in public their projects. They are described hereafter.

A. The writing dimension: Wiki environment

A wiki is an on-line editing tool that allows its users to create, comment and navigate a collection of documents that are known as entries. By extension, this collection of documents is sometimes referred to as wiki as well. With respect to their accessibility, wikis can be either of three categories. Wikis are public when any user can gain access to their contents and modify them. They are semi-public when any user can gain access to their content, but only authorized users can modify them. Finally, they are private when only authorized users can access and modify their contents.

Wikis possess the following interesting features. Firstly, since many users can edit their content they are suitable for *collaborative* applications, in which users collaborate to create knowledge. Secondly, public and semi-public wikis are visible to anyone, and therefore their contents can be *shared*. Finally, any authorized user can *revise*, *discuss* and *modify* the content created by other users. If we accept the constructivist paradigm together with student-centered approaches, these three features can make of a wiki a useful tool for the classroom:

- Projects or in general assignments that are documented by means of traditional editing tools, such as handwriting and computer text editors, usually reach the teacher and hardly a few students. On the contrary, an assignment edited in a wiki can reach the whole class no matter how large the number of students. Therefore, assignments can be shared and any student can benefit from the work of their peers.
- When the documentation of a project reaches all in the classroom, everyone can participate in the process of critical analyzing, discussing and providing feedback. Additionally, wikis provide with the necessary tools to revise and discuss each project. In other words, wikis' features facilitate peer assessment and inter-group communication.
- As opposed to other knowledge repositories such as books, that too many times are perceived as absolute and definitive, the use of a wiki can make the process of constructing knowledge transparent to students.

In summary, wikis constitute an interesting tool that provides a framework for students to construct knowledge critically and to enhance communication skills.

B. The oral dimension: Poster session

Public oral presentations constitute an excellent opportunity for students to develop their communication skills and stimulate inter-group interactions, reflection, and critical thinking and analyzing. When the number of students is limited, it is doable to promote an environment in which everyone participates. However, when the number of students is large, the most common situation is that at any time one group presents their project while the rest of the classroom act as a passive recipient. In these cases, attention is lost quickly and only the most active students from the audience participate, relegating the rest to a second plane. As a consequence, the scope of public oral presentations is greatly reduced.

Public poster sessions can overcome these difficulties while still enhancing communication skills. During a poster session, every group or only a few groups present their projects simultaneously in different stands that are distributed on the same physical space. In the same poster session, students can play both the roles of audience and presenters. Furthermore, students distribute themselves spontaneously forming small groups around a single project and as a consequence, personal interactions are greatly promoted and the average level of students' participation increases.

Another advantage of poster sessions is that students presenting their projects can increase the quality of their presentation during the session, since they present their projects several times in the whole session. This feature constitutes an interesting opportunity to promote self-reflection in students, who will try to analyze their own performance every time they present their project and will try to repeat those positive features and correct the negative ones.

III. PRELIMINARY RESULTS

For the past two years in our department, we have implemented in three courses a wiki environment using the free and open web-based software MediaWiki [10], and we have put into practice the experience with a poster session in another course. Results have been overall very positive and have encouraged us to propose the integrated learning environment that was described in Section II.

The first course that implemented a wiki environment last year was devoted to wireless technologies and involved senior engineering students [11]. The aim of the wiki approach was to enhance students' understanding of the industry sector of wireless technologies and its professional opportunities. Students were organized in small groups consisting of two or three members that were assigned the project of investigating the industrial sector of one wireless technology. They were told that the aim of their projects was to help them and their peers to understand each industrial sector by collaborating. Thus, project assignments were presented to students as a common goal, in which each group investigated one particular sector for the common benefit. Projects were documented in the wiki and course evaluation took into consideration both contents created in the wiki and a final oral presentation. Nevertheless, the possibilities of the wiki environment were not discussed in the classroom, no common format for each wiki entry was outlined and no ways of interacting between groups were considered. In other words, students were free to make the use of the wiki that they thought was the most suitable.

Students considered that compared to classic paper alternatives, the process of elaborating a wiki had been very positive and confirmed that the wiki approach had allowed them to learn about other projects, whose entries they visited regularly. Additionally, students said that the visibility of their projects had been a stimulus to increase the quality of their projects and had favored some spirit of competition among different groups. In summary, they benefited from sharing their projects and they were encouraged to be more critical about their work and their peers'. Nevertheless, we observed that they did not use all the expressivity that the wiki offered and as a consequence, wiki entries resembled a *virtual* version of classic assignment with the only difference that they were accessible to everyone. For instance, they did not link their projects to other projects and they did not attempt to develop a document structure other than linear. The degree of inter-group interaction was also observed to be more limited than initially expected by teachers.

We have tried to overcome the problems encountered last year by enhancing the role of the teacher in coordinating the wiki environment. Once again, we have implemented the wiki environment in the same course for students to document their projects [12]. However, this year we have outlined a common standard for entries elaboration. Even when this initiative limits students' freedom to use the wiki, we consider that the advantages of creating a common language and specifying basic rules overcome its limitations. Specifically, we have succinctly specified a common format for each wiki entry, including aspects such as extension and organization, use of references and use of images and intellectual property. Furthermore, we have devoted one session to discuss how to use our wiki environment, notably introducing non-linear document structures, and we have coordinated the interaction among students in the following way. Two deadlines have been established. In the first deadline, a preliminary version of each project must be available in the wiki. After this deadline, and during a week, students have to read their peers' projects and provide them with feedback to improve their assignments. Based on the feedback from their peers and from the teacher, the final version of their project must be available for the second deadline. After that, projects are presented in public. To date, projects have met the first deadline and students have provided their peers with feedback on their projects. Compared to last year's initiative, we have observed a noticeable increase in the quality of the wiki, which we attribute to the efforts to clarify the uses of our wiki. Students have said that reading their peers' projects has helped them to understand and learn about other technologies. Furthermore, the first deadline has given them the chance to reflect on their own work and some have confirmed that they will adopt some solutions found in other projects. Additionally, students have critically commented their peers' work, and they have said that the comments on their projects will definitely allow them to increase their quality.

The implementation of a public poster presentation in a course on digital image processing was very successful. Following project-based approaches, students were organized in groups consisting of two members and they were assigned one project. This initiative took place in a single session and there were altogether 15 groups. The session was scheduled as follows. During a time period of two hours and a half, teachers approached each group to evaluate their project. During evaluation, it was necessary that both members be there to explain their project and answer various questions. Meanwhile, in the rest of the groups one member had to stay at their stand to discuss it with their peers while the other could approach their peers' stands to know and discuss their projects. Halfway through the session (approximately after an hour and 15 minutes), group members would exchange their roles.

With this initiative, teachers achieved increasing students participation. Students commented in turn that the discussions that originated were open and lively. Interestingly, students agreed that repeating the presentation of their project several times gave them the chance to reflect on their exposition and continuously improve it. In fact, teachers observed that the best presentations were the last ones, probably because of this spontaneous self-improvement process. In general, compared to traditional oral presentations the poster session increased the motivation and enthusiasm among students. The success of this approach is that it facilitates that students remain active for the duration of the session, while in traditional presentations their attention span is limited to 10-15 minutes. Additionally, it allowed other students and teachers from other courses to attend and participate.

IV. CONCLUSIONS AND FUTURE IMPLEMENTATIONS

In this paper we have proposed an integrated student-centered collaborative learning environment for developing communication skills. We adopt a constructivist approach according to which, the best way of learning is by constructing knowledge. The main ingredients of our learning environment are project-based methodologies and peer-assessment, and we propose two strategies to put our method into practice. The first one is a wiki environment, and it is used to document projects, enhance writing skills and facilitate content sharing, reflection, discussion, inter-group communication, and critical thinking and analyzing. The second one is a public presentation based on poster session, and allows us to enhance oral skills, promote participation, inter-group communication, and critical thinking and analyzing.

We have implemented both mechanisms for the past two years in different courses and the results are very positive. Our previous experiences have allowed us to reflect on their outcomes and to improve their practical implementations. In the future, we will implement in other courses our integrated learning environment, by combining both wiki approaches and public poster sessions in a coordinated manner.

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Trends of Use of Technology in Engineering Education

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***Abstract*—This paper analyzes new trends on the use of technology in engineering education having as main source the Horizon Report. We discuss and analyze the predictions of this source and also other different views of the current situation in the use of technology based in the previous forecasts and the experience in distance, on-line and on-class engineering education.**

Keywords: Technology enhanced learning; engineering education; service-oriented learning.

I. Introduction

Everyday technology is having a more important role inside the engineering education just as new technologies are part of the day-to-day learning. And those technologies are implied in the learning process everywhere and in every different learning model (in the traditional on-class system as well as in on-line or distance models, which have everyday more in common in their evolution).

In the last 10 years we have had an impressive new use of technologies inside the learning process as well as communication and Internet technologies impacted previously in the last part of the 20th century. The Horizon Report (HR) [1], a work from The New Media Consortium and the EDUCAUSE Learning Initiative (ELI), has been foreseeing since 2004 the impact of the technologies inside the learning process along the world having three temporary scopes: the year of the report (short-term), the next two years (mid-term) and finally, the four years following the report (long-term).

II. Objectives

We will use these predictions from 2004 to 2009 (six Horizon reports) that will cover the period 2004-2013 to analyze the technologies that will have a higher impact in education.

We will also discuss about the technologies not covered in the report and that we believe will also have a great impact in the engineering learning near future. In this process we will keep in mind the expertise from previous engineering technology projects as well as the knowledge shared in different technical conferences that provides a guide of the most used technologies around the class-rooms.

With all this information together we will develop a structured view of the foreseen technologies that will have an active role inside the engineering education process, providing our agreement or not with these predictions. On the other hand, the study will include the not forecasted technologies in the past that have been really used in the practice today. Finally we will analyze the technologies that currently and in a near future could have a great impact in our engineering education.

III. Methodology

The first stage on this research is to gather the technologies identified in each one of the six existing Horizon Reports. These technologies are structured according with the three adoption horizons: short-term, mid-term and long-term.

This work provides information about the technologies that have been identified as the more likely to impact since 2005 to 2014, but with the benefit of a temporal perspective.

The second stage is to create a visual representation of the results, using different colours to differentiate the technologies obtained from the different reports. This work provides an overview of all the technologies involved in the educational environment during the last years and also the most promising technology for the near future.

The third stage is aimed to group technologies according with their similarities and create particular views of each technology group. This work will help to detect where the technology flows are going to and what technologies have finally impacted on the educational environment and on contrast, what others have postponed their implantation or just have never arrived.

Finally, the fourth stage has as main objective to provide comments about what technologies have impacted in the educational environment and do not appear in the research.

IV. Most likely technologies to have an impact on education

According with the stage 1 of the proposed methodology, the following temporal diagram (Figure 1) represents the technologies that Horizon Reports considered as the most promising to have impact on education.

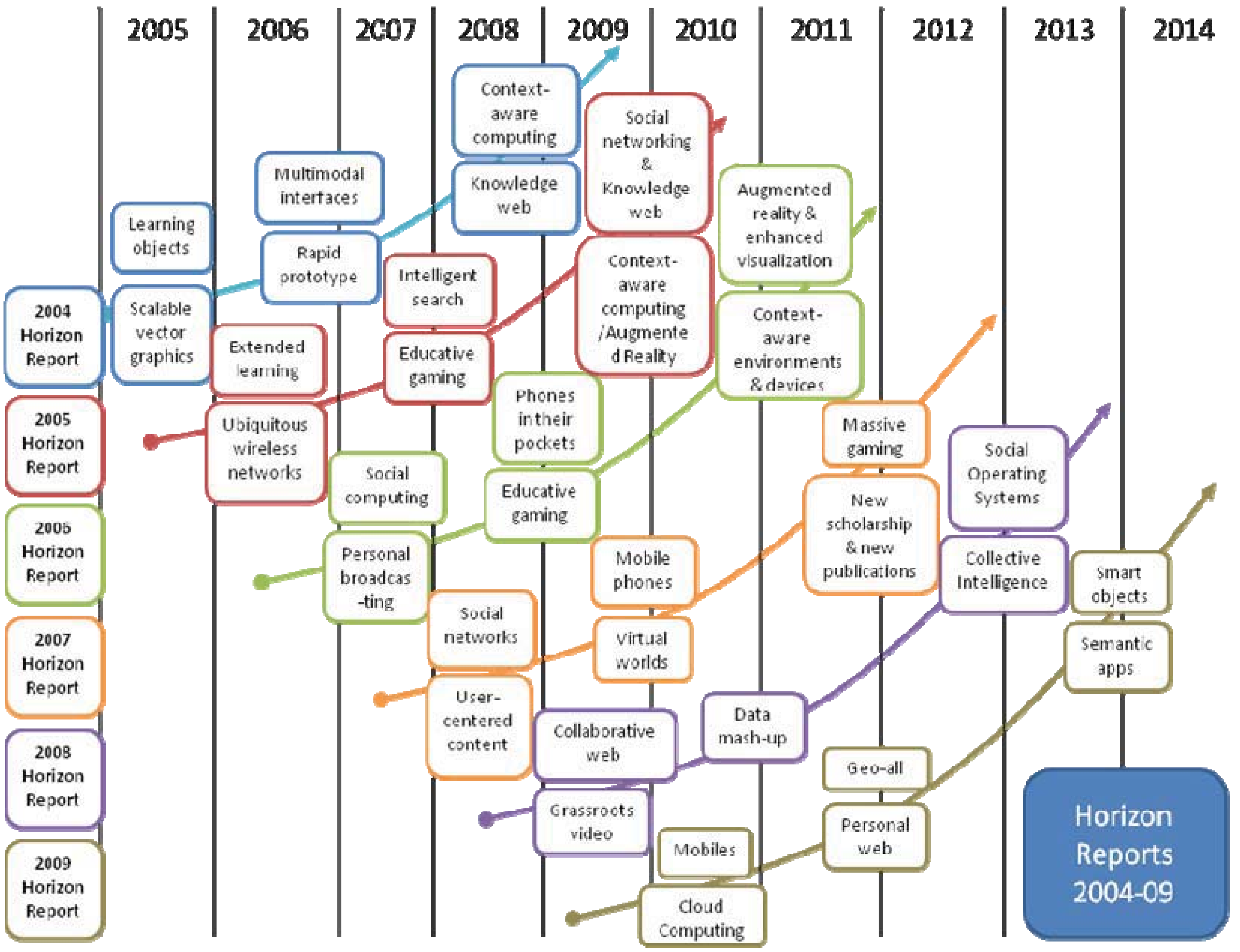

Figure 1. Most likely technologies to have an impact on Education according with Horizon Reports from 2004 to 2009.

In figure 1, each one of the six Horizon Reports is represented in a different colour. And also everyone provides two technologies in each term (short, mid and far) placed in their suitable temporal range.

These technologies can be structured in six technological groups that will simplify next stages. These groups are the following ones:

- Knowledge-Web. It includes cloud computing, which is based on the use of educative services on the cloud. It also includes the called Personal web, which is aimed to reorganize and customize the web according with the preferences of the students. Besides other technologies, in this group it is possible to find technologies that support knowledge representation (learning objects). These technologies are the basis for the arrival of others such as intelligent search engines and semantic-aware applications (understanding of the meaning of the web content); etc.
- Augmented reality. This technology provides additional information to the real world with interactive features. It can be used on both desktop-based computers and mobile devices.
- Social networking. It is aimed to enhance the collaboration and communication among students through moving the social networks phenomenon.
- Ubiquity. It includes smart objects (the Internet of Things within the education environment. It involves technologies such as RFID, QR codes, NFC or smartcards);
- Educative games (both on desktop or mobile computers, helping learners to be immersed in a virtual world that offer them a deeper understanding of the concepts).
- Mobile devices (thanks to new interfaces, location-awareness, broadband connectivity, etc.) and Geo-everything (mainly related to mobile devices);

These technologies will be studied in more detail in the following points, providing a temporal graphic for each one, which will help to analyze the technology flows.

V. KNOWLEDGE WEB

The use of Web-based technologies in education does not suppose any innovative approach. However this research focuses on the arrival of technologies that will support the development of the called 'Knowledge Web' [2]. It is based on three key trends: knowledge representation, mainly through some kind of meta-data or structure language; knowledge generation through collaboration; and personalization of the gathered knowledge (Figure 2).

The first trend was forecasted in the reports for the first time in the 2004 HR, with the arrival of learning objects (forecasted for 2005) and knowledge-web, basically based on technologies such as RDF or RSS (forecasted for 2008-09). The 2005 HR also forecasted it as an important technology to have into consideration, but in this case closely related with social networking (implantation in 2009-10). These technologies are today totally implanted.

The second trend is related with collaboratively creating and sharing knowledge, using the representation schemas previously created. Within this concept we can also find the personal broadcasting, forecasted in the 2006 HR for its arrival in 2007, and based on the idea of a user that will create its own multimedia content that will deliver to others through the Internet (e.g. YouTube-like tools). In addition, regarding also this trend, the 2007 HR included as key technologies for 2008 the creation of user-centred content (the user actively becomes author of the content, not just a listener, as in the case of blogs, wikis or video-web creation). In fact, as this technology was rightly a fact, the 2008 HR saw the impact of more advanced collaborative technologies, as data mash-ups (forecasted for 2010-11). These technologies merge knowledge from different sources (pictures; real state; entertainment, academic or corporate information) into other tools (e.g. maps and social networks) getting an added value from the raw knowledge. The impact of this technology will be considerably more important when the knowledge sources used to mash-up were based in a collective work (as Wikipedia is). This kind of applications are not far to be a reality. In fact, the 2008 HR forecasted its impact on education for 2012-13 (long-term horizon).

And finally, the technologies from the third trend are related to searching and getting personalized knowledge, based on the previous knowledge representation. Regarding the searching, the 2005 HR provided details of the implantation of intelligent search engines (e.g. federated searches, such as Blinkx and Google Scholar or Desktop) in a mid-term horizon (2007-08), which is a totally implanted technology today in the educational environment. This concept is the basis of semantic applications, forecasted in the 2009 HR to impact in a long-term horizon (2013-14). It is based on the idea of systems able to extract meaning from the information in the Web and giving personalized services and information more according with the user's needs.

On the other hand, regarding the personalization, trends seem to tend towards the personalization of the content, services and knowledge that the user receives. It specially reflected in the 2009 HR, which forecasted the impact of the personal web (self reorganization of Web content, using technologies such as RSS or Widgets) for 2011-12.

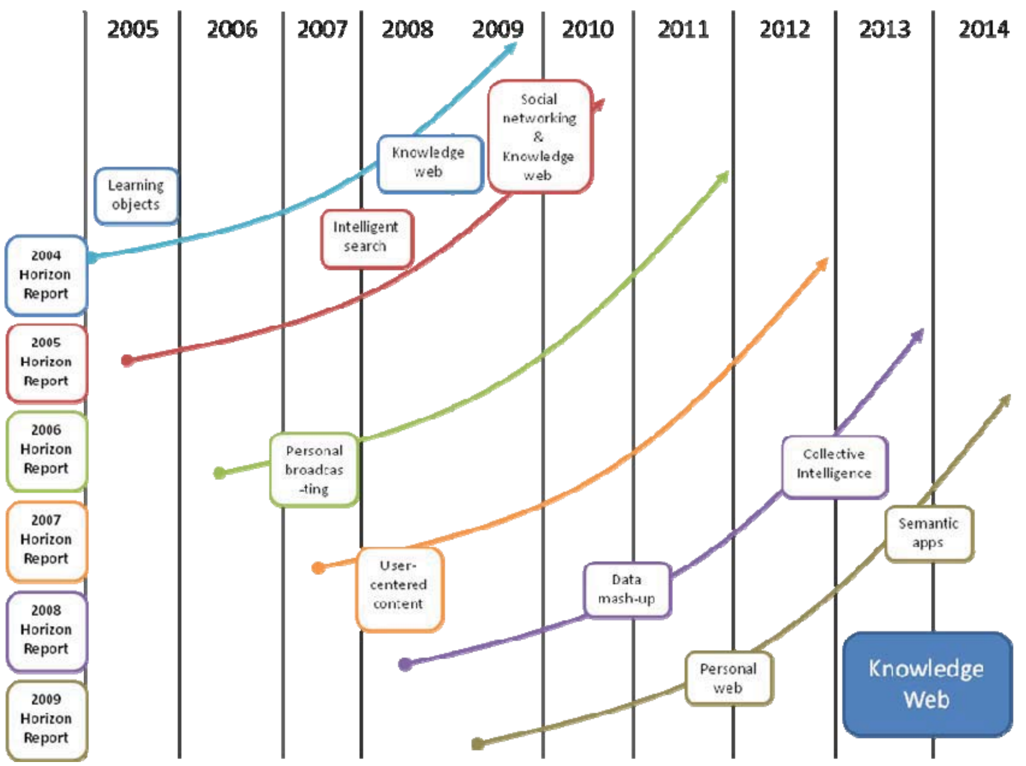

Figure 2. Most likely Knowledge-Web technologies to have an impact on Education according with 2004-09 HR.

VI. AUGMENTED REALITY

Augmented Reality (AR) is a technology that basically merges information or images with video-streaming from a Web-cam [3]. The result is similar to virtual reality but using real-world images in real-time. Some of the many potential revolutionary applications in education are related for example with the study of architecture, art, anatomy, decoration, or in general anything that a graphic, a simulation or a 3D model could improve the comprehension of the concepts. The forecast (Figure 3) in this field started in the 2005 HR, as a long-term promising technology (placed on 2009-10), and the next HR (2006 HR) delayed its arrival one more year (2010-11). Today, it still seems to be far from real implantation. Nevertheless, although any other HR has made any mention to this technology, it is still a promising technology. The proof is that some other technologies, apparently unconnected, are being developed and successfully implanted. As an example, the 2004 HR forecasted the implantation of Multimodal interfaces (i.e. the use of not only keyboard and mouse as input methods, but also others such as motion sensor, location, etc) and Rapid prototypes (i.e. creation of 3D models through CAD, CAT or even X-ray). These technologies are also related to AR, as 3D is one of the basic pieces of information provided, and the use of multimodal interfaces support the interactivity with the simulation just moving around it (motion and location sensors).

Reports also show other examples, such as mobile devices, that were forecasted in the 2007 and 2009 HR to have its arrival along 2009 and 2010.

2007 HR was also focused on user-centred content (forecasted for 2008). This technology is based on the concept that the user is no longer a mere listener, he/she will participate in the creation of any kind of material: videos, wikis, 3D model, etc to be mashed-up in geographical systems. This technology matches the conception of AR, as it is based on providing valuable material over real world images. Therefore, the experience will be more enriching as long as the user has more accessible contents. These two technologies specially converge when we talk about 3D models or information to be placed over a particular location. Along these lines, reports also show that other technologies such data mash-up and geo-all (2008 and 2009 HR respectively) will make its arrival between 2010 and 2012, when in fact, they are quite extended technologies. These technologies are closely related with the previous one because of the need of mashing-up content with location capabilities. Finally, other technology that apparently is not related to AR is Smart Objects, which is partially based on the concept of tags (RFID or QR). This tags support the tagging of our surrounding environment, helping us to provide it some kind of intelligence. This tags are also one of the key factors for AR, due to the fact usually the matching between real world images and computer-based information is through this tags. It means that when the AR system finds one of these tags, it changes it for the desired simulation or information.

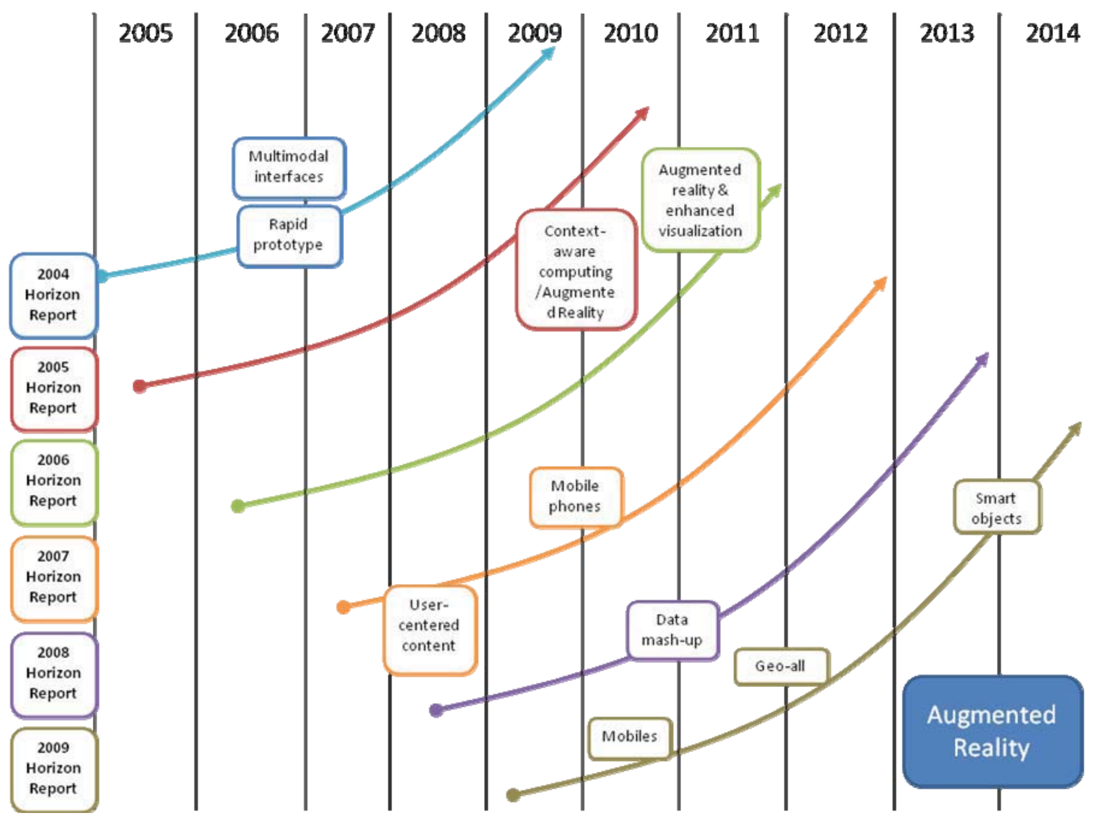

Figure 3. Most likely AR-related technologies to have an impact on Education according with Horizon Reports from 2004-2009.

VII. Social Interaction

The social phenomenon is one of the most promising technologies, as the amounts of technologies of this area that have been forecasted demonstrate (Figure 4).

The 2005 HR already forecasted the importance of the Social Interaction, through the arrival of collaborative tools for communication among students (called extended learning) in a short-term (2006), as it already was a widely implanted technology in other environments. This report also predicted its importance when it forecasted the use of more advanced tools in education, as social networking, in a long-term (2009-10).

The 2006 HR also reflected this fact, focusing on virtual collaboration tools (Social Computing) and broadcasting of user-created content (Personal Broadcasting), such as blogs, wikis, and audio/video based tools (its impact was forecasted for both during the year 2007). This last concept appears in the 2007 HR as user-centred content to have impact in 2008. Moreover this report shows the imminent arrival (2008) of a widely implanted technology in entertainment environments: Social networks. This phenomenon is based on the idea of providing advanced communication tools and the creation of a network of contacts, supporting a totally engaging environment. This report also focuses in a mid-term horizon (2009-10) on virtual worlds, which are the evolution of social networks towards totally immersive environments, where the user plays a role inside a virtual world. This report also describes the impact of Massive Multiplayer On-line Games (MMOG) in a long-term horizon (2011-12). Here the user plays with thousands of other players an engaging on-line game, which is active 24 hours per day. It means that the game goes on, although the user is not connected. In these games, every player has a specific role inside the game. It usually involves the development of complex tasks, such as a pharmacist that has to create pills to sell to doctors, which will use these pills to heal warriors in a battle. These tasks involve the development of many skills and knowledge in a very engaging environment. For that reason, education should not leave it aside of the academic environment.

On the other hand, the 2008 HR is again focused on the use of collaborative systems in a short term (2009), especially those focused on the Web, such as the use of collaborative tools to edit documents in group or sharing videos with a community. In the mid-term horizon (2009-10), data mash-up is introduced as a key technology. It is based on the idea of overlapping information over geographical systems. And finally in the long-term horizon (2012-13) the forecasting focuses on social operating systems, which promulgates the organization of the social networks around people instead around content. The other technology forecasted, in this report and in the same term, is Collective Intelligence based on the knowledge generated from large groups of users, such as Wikipedia or passive search patterns.

In brief, the social networks phenomenon has widely proved its power of engagement, and its capabilities to create collective knowledge [4] from the work of a group, which is more than enough to take it into consideration in education.

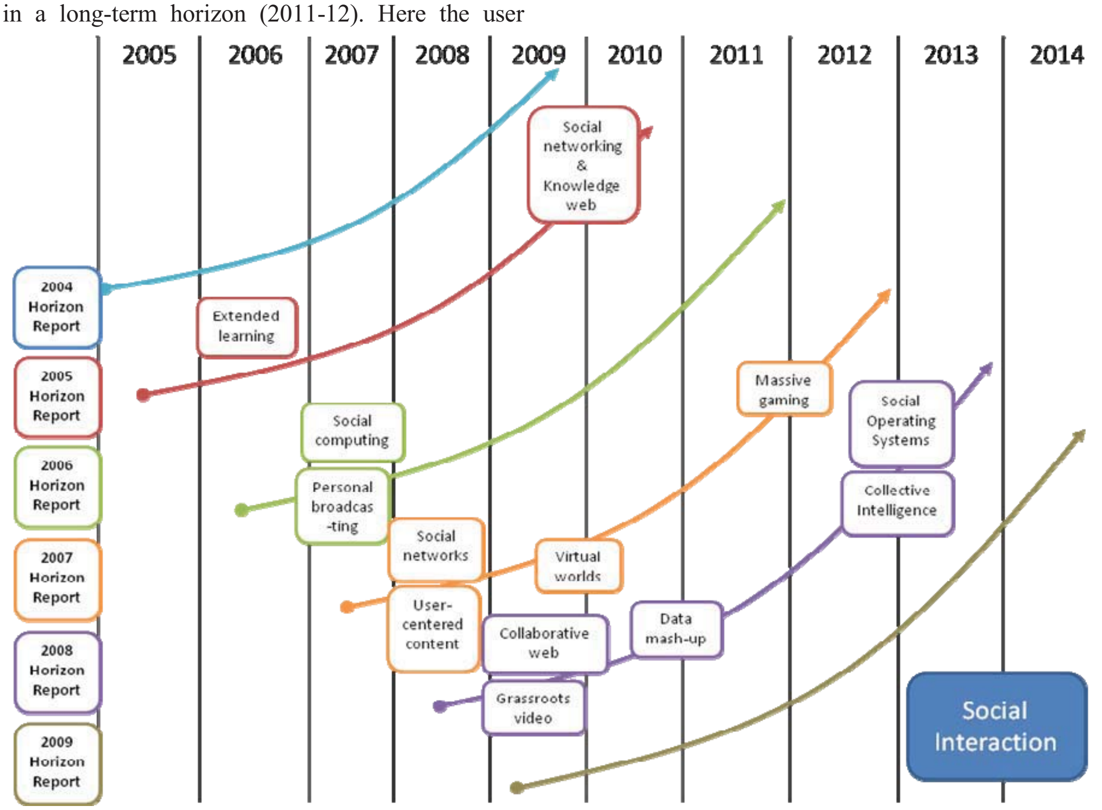

Figure 4. Most likely social technologies to have an impact on Education according with Horizon Reports from 2004 to 2009.

VIII. UBIQUITY

Ubiquitous computing is based on the concept of an invisible computing power embedded in the environment that can act and react according with user's needs. This paradigm involves the most natural possible interaction between user and computer with the final aim that the user will not even realize that is interacting with a system [5].

Ubiquitous computing is not a technology itself, but a group of technologies that will support the arrival of this new paradigm such as: context-aware computing, ubiquitous wireless networks, smart objects, location-based systems and more recently mobile-based technologies. For many years many of these technologies have been considered by experts as some of the most promising technologies to have an impact on all levels of our society (Figure 5). But the truth is that its arrival has been delayed.

In the 2004 HR, context-aware computing was foreseen as a key technology in a long term horizon (2008-09). In the 2005 report, an important technology for this paradigm appeared as implanted or in process of implantation in a short term: Ubiquitous wireless networks. In fact, it is one of the key requirements to support the arrival of ubiquitous computing, but experts again foreseen its implantation in a long term (2009-10). In the 2006 report, the phenomenon of mobile devices in education seemed to be a reality in a mid-term (2008-09). Context-awareness arrival is again delayed until 2010-11, although mobile devices could act as catalyst. Mobile devices were corroborated in the next report, but delaying its arrival one year (2009-10).

In the 2009 HR this paradigm returns as a promising technology. Here, mobile devices appear as a technology to be implanted in a year-term, as probably will happen. Obviously this implantation will not be worldwide, and cannot be seen in all the centres, but it will probably start becoming a reality.

Regarding with the other key-technologies in this report, it is interesting the impact in a mid-term (2011-12) of location-based technologies (geo-all). It is a fundamental piece of the puzzle, due to the fact it allow retrieving a very important part of the context (where the user is) to use it in a great variety of applications (e.g. just giving personalized services and information according with the location or integrating it with data mash-up systems). On the other hand, smart objects (Internet of Things, RFID systems, etc.) are forecasted for a long-term horizon (2013-14), which will allow to provide some intelligence to common objects.

The role of mobile devices in education started just as the basis of a very rudimentary mobile learning, but with the integration of ubiquitous computing and context-awareness paradigms, such as location-based technologies its functionalities are being extended to provide a real improvement on the learning experience [6]. The success of mobile devices in education in a short-term and its integration with ubiquitous technologies will probably foster the arrival of ubiquitous learning in a few years.

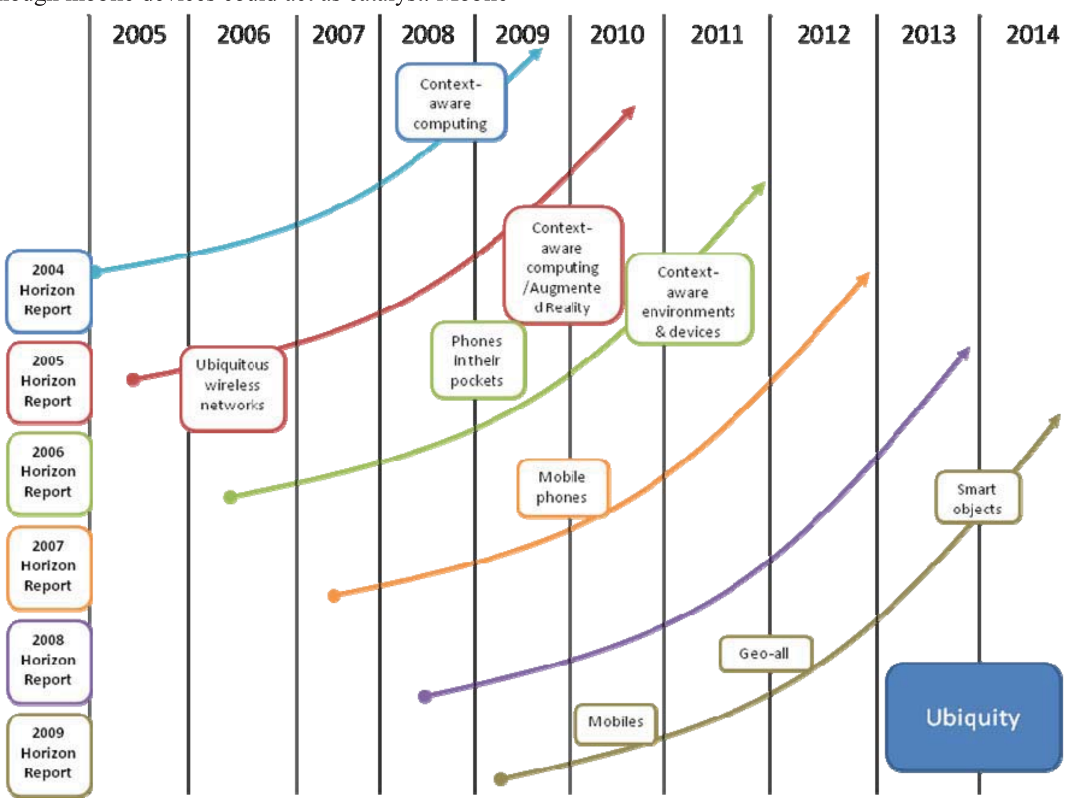

Figure 5. Most likely ubiquitous technologies to have an impact on Education according with Horizon Reports 2004-09.

IX. Mobile devices

Today's generation has grown with a new kind of technologies that the previous generation might not have imagined: cell phones, Smart-phones, portable video-consoles, GPS navigators, etc. Mobile devices have deeply impacted in our society changing the way we communicate and keep in touch with each others. Nevertheless today mobile devices are not just a communication method as the telephones are [7]. Today mobile devices are also changing the way we work, supporting any kind of applications (further of the typical office apps, Internet, and e-mail); spend our spare time with video games, Internet videos, podcasting, etc; get information, through GPS navigators, augmented reality or just surfing the Web; or even education. This field is where we are most interested in. Currently mobile learning is a promising technology that goes further than the traditional content-delivery by SMS or Web.

According with the studied HR's it is not until 2006 when for the first time experts think phones will have an impact on education. They foresee it in a midterm, it means in the 2008-09 period. This prediction has not been changed like the next report (2007 HR) only postpones it one or two years (until 2009 and 2010). Finally the 2009 HR place its implantation in a short-term horizon, it means for the 2010. Although there are only these references to this technology in the reports, its development has been accompanied by other related technologies such as location-based systems (context-awareness) (2004 and 2005 HR). Thanks to this technology it is possible to provide personalized services to a student according with his/her profile and location, therefore this involves a mobile device. As we have previously studied these ubiquitous technologies were foreseen to impact in education firstly in 2008 but its arrival has been constantly delayed.

Other important related technology is wireless networks. This is a key technology to support the success of mobile devices due to the fact anytime and anywhere connectivity makes the mobile device not being isolated but another part of the environment. Its arrival was foreseen for 2006 (according with the 2005 HR), and currently wireless networks are a reality anywhere (Figure 6).

The only related technology foreseen in the 2006 HR is data-mash-up. It supports merging useful educational information into maps to provide an added value. Its implantation was foreseen for 2010-11 but is today fully implanted (2009). This concept also appears as Geo-everything in the 2009 HR for 2010-11 (mid-term horizon) but with the particularity of the use of data mash-up in mobile devices using the location-based features (context-awareness).

Finally the last related technology is personal web. It is based on the concept of reorganizing the Web instead of just viewing it. It started mainly for desktop computer but thanks to the proliferation of mobile devices it is very likely to have impact in education with both devices at the same time. It was also foreseen in the 2009 HR to impact on a mid-term horizon so its implantation should be around 2011 and 2012.

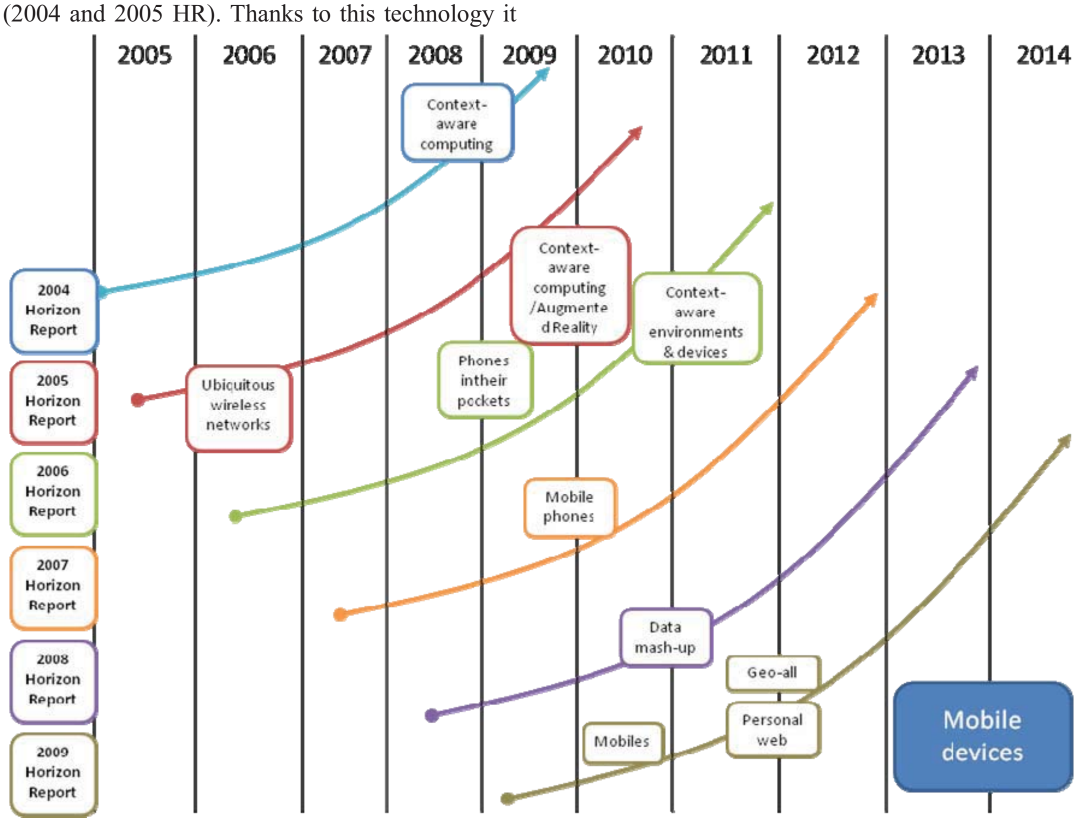

Figure 6. Most likely mobile technologies to have an impact on Education according with Horizon Reports from 2004 to 2009.

X. Games

As we discussed in the previous chapter, today's generation are used to other kind of interaction. New generations demand more interactive and engaging materials for learning. Since this is the way they have acquired many of their cultural knowledge. Many students spend many hours watching attractive contents on TV, surfing personalized contents in the Internet or playing engaging games using their desktop computer or their mobile phone.

This fact makes necessary a change in the way of teaching or even better in the way of learning. New generations are not usually engaged with lectures in a classroom. Therefore many research efforts have been accomplished in order to create engaging games to support learning and not just for fun.

Along these lines the 2005 HR (Figure 7) forecasted the implantation of educative gaming in a mid-term horizon, i.e. between 2007 and 2008. Probably, the next report (2006 HR) again forecasted its implantation in a mid-term (2008-09), i.e. one year later, as this learning methodology had still many detractors.

The 2007 HR focused on two related technologies: Virtual worlds (forecasted for 2009-10) and Massive gaming (foresaw for 2011-2012). The reason is that both environments had successfully reached an important part of the society by 2007, so it was very likely also to impact education in a few years. In many aspects of our society Virtual Worlds have deeply impacted, giving rise to a parallel world, where people work, communicate, earn money, spend it and even receive education. Maybe the difference with reality, and the basis of its success, is merely the opportunity to do it without the fear to failure. When all is said and done, virtual worlds are just games and you always can start again. On the other side, massive multiplayer games also own the same engaging component, as they are also basically virtual worlds, but with a clearer objective: to defeat the enemies, to save the princess or to get the best scores.

These both predictions could make to suppose the idea of continuity; therefore this methodology should also appear in the following HR. But in fact, none 2008 and 2009 HR mentioned anything about it again. Maybe the reason is the mentioned doubt of a great part of academics who do not believe it can really contribute to education. Some of the allegations against educative gaming are the high-cost of game development (both economic and timing), its difficulty for non specialist (which is currently being improved through open source engines) and finally the required creativity for its creation. The reason is that it can be difficult to teach in a different way to this you have used to learn.

Nevertheless, some attempts are being done to move the power of games and virtual worlds towards companies [8] but not for training but for serious work due to its engaging power in repetitive jobs (e.g. a call centre). If games finally get to enter into serious companies, it is very likely to assume its final arrival to education.

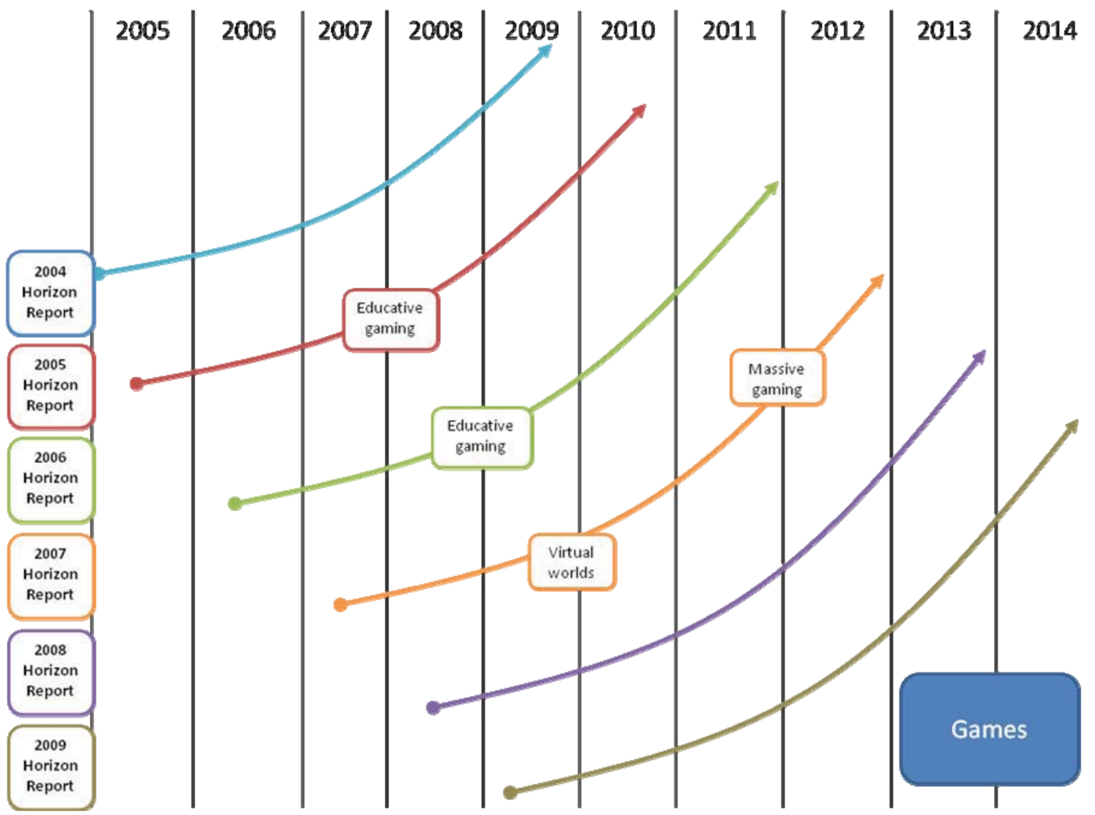

Figure 7. Most likely gaming technologies to have an impact on Education according with Horizon Reports from 2004 to 2009.

XI. Other promising technologies: Services

In addition to those already studied and grouped, there is other technology that will likely have an important impact on education, or better yet, on the way education is going to be built in the coming years. Some authors call this trend 'service-oriented learning', 'service-based learning' or 's-learning' [9].

This technology is related to the concept of learning object already forecasted in the 2004 HR to have impact on 2005, and also to the concept of Cloud Computing, forecasted in the 2009 HR for its impact on 2010. Likewise it is based on the idea of having different services available on the Internet (on the Cloud) that can be used and integrated regardless its physical location.

This service-based trend is based on the concept of modelling the educative services with the objective of providing better interoperability capabilities in different levels: service-services, platform-platform and service-platform. Equally it is based on the encapsulation of services, as the learning objects are, to develop autonomous and self-contained services that can be easily integrated in different environments such as Learning Management Systems, mobile learning environments, remote laboratories or assessing tools. Within this concept, there are many subjacent technologies that are its foundations, such as Web Services and Cloud Computing. Also there is another surrounding concept such as the Digital Ecosystems [10], which is based on the idea of creating environments made of different systems integrated in a plug-and-play way. It is achieved through the use of technologies such as SOA (Service-oriented architecture), ESB (Enterprise Service Bus) or ontologies.

Although emerging, this concept is getting more importance on education, and is becoming one of the key technologies as developers are realizing the necessity of reusing services not only inside the same platform or programming language but also among different platforms and architectures.

XII. Trends and flows: Technologies that seem not to impact and convergence

During the previous categorization and analysis we have detected some promising technologies that finally have never impacted on education.

As an example we find Ubiquitous Computing. Although this concept was firstly forecasted by the 2004 HR to have impact on education by 2008 it has not even had the expected impact on any of the other aspects of our society. But although slowly is getting a place in the industry; it is still too small to propagate its effects to education. For that reason it seems obvious we will have to wait until it finally takes the important place that seems to belong to see its effects on education.

On the other hand, mobile devices should be observed from a different prism. This technology has deeply affected our society, especially with the new wave of Smartphones, such as the iPhone or those based on the Android or Windows Mobile operating systems. The incorporation of new features such as location or motion sensors are giving rise to a revolution in the way people use these devices.

In fact, partly motivated by this revolution there is a technological trend that is making converge many of the technologies studied here into one. For example, thanks to the appearance of new multimodal interfaces, wireless networks and context-aware technologies (such as those related with location and motion sensors) mobile devices are getting more important. At the same time other promising technologies such as social networks are starting to arrive also to the mobile environment that seems to power even more these devices with never-seen communication capabilities.

Other key-technology for the near future is Augmented Reality, which is becoming also to be implanted in mobile devices providing more flexibility and variety of applications. The new range of environments that can be affected by the combination of both technologies is enormous. For example, in education, this technology in books and magazines could revolutionize the way people study or spend their spear time just providing additional multimedia information over the books through the mobile device. Other relevant example could be for out-of-the-class activities such as those related to agronomy, archaeology, history, natural science, and in general any subject which an in-the-field or challenge-based work that could provide an improvement on the learning experience. At the same time, this is closely related to games because they are based on the concept of challenge. In addition, mobile devices strengthen even more its engaging capabilities because are themselves attractive devices especially with the incorporation of more natural ways of interacting, such as multi-touch screens, motion and light sensors and location capabilities.

Finally, the last key group of technologies studied is also converging with mobile devices as their new operating systems are developed with the idea of simplifying the access to the information and the personalization of services. As an example we find the Google personalized searches depending on the user's location (from cell-tower triangulation or GPS) or the quick access to relevant information of the user through the utilization of Widgets and RSS.

In conclusion, mobile devices are called to be one of the most important technologies on every layer of the society in a near future including of course education. It will be the technology base for the successful arrival of many other promising technologies like:

- Ubiquitous computing
- Social networks
- Augmented reality
- Games
- Personal Web

XIII. Conclusions

This research is aimed to clarify which of the main technologies are called to have an impact on education according with the history provided by HR. This analysis tries to provide a perspective on the evolution of some technologies towards others. Having the aim to support a better understanding of the technology flows in the past and to predict what could be the future.

The result is that there are six groups of technologies that are converging into one: mobility. However, it does not mean they are going to disappear and mobile devices are going to be the most important technology. In contrast, these groups of technologies will go on getting more importance, through different branches; and being enforced thanks to the flexibility and synergy power that mobility provides. And at the same time, mobile devices will probably be enforced thanks to the growth of the other convergent technologies, because it will be a tool able to support all of them.

As a conclusion and using the results of this analysis, authors consider important the development of strategies and architectures able to support the forecasted convergence and integration of different technologies into mobile devices. The objective is to provide suitable communication methods and interoperability among these technologies, in order to support their better development.

XIV. Acknowledgements

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Ranking Learner Collaboration according to their Interactions

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Abstract— **Collaboration is supposed to be easily implemented in Learning management systems (LMS). Usually the basic functionalities in that respect support grouping students and providing communication features so that they are able to communicate with each other. However, related collaborative learning and CSCL studies and developments, which have been investigating how to manage, promote, analyze and evaluate collaborative features for decades conclude that there is no easy way, and much less standards-based approaches to support effective collaboration. The mere use of a typical set of communication services (such as forums, chat, etc.) does not guarantee collaborative learning. Further, managing collaborative settings in those LMS approaches is usually a time consuming task, especially considering that a frequent and regular analysis of the group's collaboration process is advisable when following and managing the collaborative processes. To improve collaborative learning in those situations we provide tutors and learners with timely information on learners' collaboration in a domain independent way so that the model can be transferred to other domains and educational environments. After setting a collaborative experience in an open and standards-based LMS, we have analyzed, through various data mining techniques, the learners' interaction in forums during three consecutive academic years. From that analysis we have built a metric with statistical indicators to rank learners' according to their collaboration. We have shown that this rank helps learners and tutors to evaluate the collaborative work and identify possible problems as they arise.**

Keywords- Collaboration, Data Mining, Distance Education Learners

I. Introduction

The current web-based Information and Communication technologies (ICT) bring people closer together. In particular, Learning Management Systems (LMSs) use the ICT's so that learners can interact with educational contents and other learners. Collaborative strategy can be implemented in those LMSs to improve the learning and mitigates the typical conditioning factors (loss of communication quality with fellow students and teachers) of the distance education [2]. Even AI techniques have been applied to model mainly learners and their knowledge [7]. However, collaboration so widely used and useful in educational environments has not been deeply researched and a standard method to analyze collaboration has not been established [24]. Although some research works have focused on collaboration [25], the proposed methods are difficult to transfer to other educational environments [21].

Moreover some researches claim that collaboration analysis is necessary to verify that collaborative learning takes place [14] and the metacognitive information on collaboration, which is obtained from the analysis, helps learners to improve the control on the learning and collaborative process [10].

In this paper we propose an approach to rank learners' collaboration according to their interactions. The objective is to help learners to improve the collaboration process through a method that both provides information on learners' collaboration, and can be used in others LMSs. Accordingly we focus our approach on a quantitative analysis of interaction data in an open-collaboration learning environment.

The educational context of our research is suitable for collaborative learning, because our learners at UNED (The National University for Distance Education in Spain) are used to the distance learning model. UNED's students are mainly adults with responsibilities other than learning. For this reason UNED's students cannot be forced to collaborate in a typical CSCL where they are requested to meet demanding time restrictions and fixed collaboration patterns [12]. We have solved this problem by providing learners with an open collaborative learning experience supported by an LMS, where students could manage their own collaborative learning process. We designed a long-term collaborative learning experience with 4th-year Artificial Intelligence and Knowledge-based Engineering (AI-KE) students. This experience consisted of 2 main phases within a step-wise approach: the first phase covered 3 consecutive weeks and the second phase covered 10 weeks. It was enough time for students to complete the collaborative work and be able to manage their collaborative process. We offered the collaborative learning experience during the academic years 2006-07, 2007-08 and 2008-09, and more than 100 learners every year participated in the experiences.

To cover the objectives, we proposed an approach based on quantitative analysis of the learner interactions in forums. Forums are a very common service in a collaborative environment and the statistics from forums can be obtained just after the interaction has occurred. We propose building a metric with statistical indicators, which are related to learner's collaboration. First we suggest some statistical indicators, which describe the initiative, activity, learner constancy and activity caused by learners. As the relation between statistical indicators and collaboration is unknown, we have used machine learning algorithms to reveal the relation. After the machine learning analysis, we found that the most collaborative learners are learners with high and constant initiative, high and constant activity, and they caused more activity than others. After the machine learning algorithms had selected the statistical indicators, we built a metric to rank learners according to their collaboration. We conclude that the ranking is an approximation of learner collaboration.

A short overview of methods already used in evaluating the collaboration process is given below. We describe the collaborative learning experience and the inferring method. Next we show the results obtained afterwards by applying the inferring method and we explain in depth how the inferring information has been shown to learners. Finally, we conclude with the discussion and future works.

II. Related Works

There have been various experiments to measure or identify the collaboration that is taking place between users of a system, although the methodology and standards are scant to analyze collaborative educational environments [24]. We mention two main points of research works, which focus on collaboration: data acquisition and inferring methods.

We can identify three data acquisition methods: 1) Qualitative [18, 15]: where participants are asked directly or experts evaluate the activities of the participants. 2) Quantitative [25, 21, 13, 5], which collects statistical information on the activities of the participants. 3) Mixed [8, 9, 17, 19]: the use of both methods simultaneously.

After the data had been collected, they were then analyzed using several techniques. These systems can be characterized by the inferring methods used. The methods may include: 1) Analysis by an expert [18, 15]. 2) Comparison with a pre-existing model using machine learning methods [21]. 3) Different statistical techniques [13, 9, 17, 5], or machine learning, such as clustering [25, 19], fuzzy logic [21], sequential pattern mining [19]; 4) Systems can even be characterized by not using any inference method [8, 9, 17].

Some research works focused on the experts' analysis to obtain evaluations of the collaboration [18, 15], others monitored learner interaction to improve collaboration knowledge but they did not obtain any evaluation of the collaboration [8, 13, 9, 17, 5] and some others used machine learning algorithms to analyze collaboration, although the expert's analysis is necessary [25, 21]. For this reason the regular and frequent evaluation of the learners' collaboration are delayed or the approach cannot be transferred to other learning environments.

We propose an approach to obtain evaluation of the learners' collaboration in a frequent and regular way, and reusable in other collaboration environments. This evaluation rank learners according to their collaboration. The approach uses both statistical indicators of learner interaction without semantic information and also the expert's analysis of collaboration as a data source, and machine learning algorithms to relate the statistical indicators to the expert's analysis of collaboration. With the statistical indicators most related to the expert's analysis we propose building the metric to rank learners.

III. Collaborative Learning Experience

The loss of communication quality that usually affects the distance education environment can be solved, if collaborative learning strategy is used [2]. However, the collaborative learning strategy must be focused on the learner to use all advantage of collaboration [11]. The distance education learners can be characterized by their diversity (different ages, residence, background, objectives, experience, etc) [4]. These learners are used to managing their own learning process, because they have responsibilities other than learning. Thus, a collaborative learning experience must allow the learners to manage their own collaboration process.

We offered learners a long-term collaborative learning experience during three consecutive academic years; 2006-07, 2007-08 and 2008-09. The collaborative learning experience provided learners with enough time to perform the tasks without the typical time restrictions of CSCL systems.

The learning experience consisted of practical collaborative tasks, which covered 3 months of an annual subject on AI at the Computer Science School. The activity structure was divided into 2 main phases within a step-wise approach. The collaborative learning experience was offered to all students enrolled in the subject. The Figure 1 shows the learning experience schema.

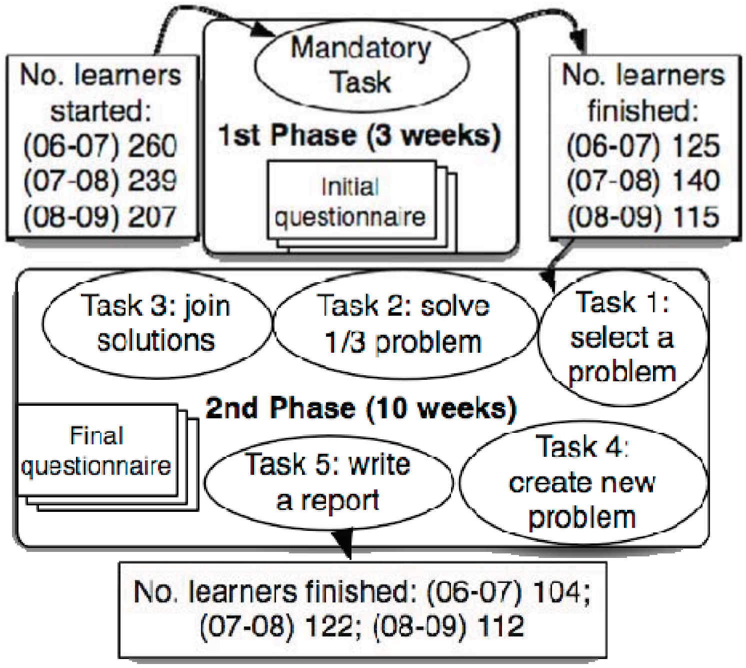

Figure 1. Learning experience schema

The first phase went on for 3 consecutive weeks where the main learner tasks were answering an initial questionnaire and solving an individual task. The questionnaire asked personal data and information about their willingness and availability to collaborate with one another. The individual task was mandatory and its results had to be integrated with the collaborative work to be performed during the second phase.

The second phase covered 10 weeks and the learners were grouped in 3-member teams. The team members had to follow 5 consecutive tasks throughout the collaborative experience. (1) In the forums teams discuss which problem they are going to address from the ones that are given to them. (2) This task is mainly individual work and consists of each team member solving one of the three different subproblems. (3) The team members have to integrate their previously generated individual solutions. (4) The experimental task takes place in this phase and here the team has to create other related planning problems that are based on the original one. (5) Finally, the team has to provide a report that covers all the activities and their corresponding results. At the end, the learners were asked to fill in a final questionnaire, which includes several topics with valuable information associated with the collaboration results. The team-work increases the difficulties depending of the done tasks, from the easiest (Task 1) to the most difficult (Task 4). Thus, the learners can be developed and improved the collaboration skills [16].

The whole range of activities included in the collaborative learning experience was supported by the open and standards-based learning platform dotLRN [23]. This learning platform stores all the interactions, which take place on the platform, in a relation database. During the first phase a general virtual environment was open for all students. The general virtual space included several services to support their collaboration needs, such as the file storage area, FAQs, news, surveys, calendar and forums. During the second phase a virtual spaces were opened for each 3-member team, where they could perform the tasks. The specific virtual spaces included documents, surveys, news, task manager and forums.

IV. METHOD

To know the collaboration learning happens, a frequent and regular analysis of the collaboration is needed [14]. In the aforementioned collaborative learning experience the learners have the control of the collaboration process. The tutor has difficulties to analyze the collaboration of all learners and teams in these circumstances. However, machine learning techniques can be used to analyze the learners' interactions to infer evaluations of the learners' collaboration.

The research objectives were twofold. Firstly, to build a domain independent method, which was capable of identifying the interaction features that were more relevant to support learner collaboration. Secondly, providing collaboration managers with timely results so that they could provide corrective actions wherever appropriate. We argue that quantitative data can support the overlapping required between user interactions and corrective actions. Besides, quantitative data without domain information (for instance, quantitative data without semantic analysis of forum messages) make it easier to transfer the method to other environments, because the data are domain independent. Our hypothesis was that the statistical indicators derived from learner interactions in forums could support both requirements, i.e. domain independency and simultaneousness.

We proposed a set of statistical indicators to characterize the forum interactions. We built datasets with these indicators and the dataset was labeled with information on learner collaboration. An expert, who was the tutor throughout the whole collaboration experience, supplied this information. We used machine learning algorithms [3], decision trees, to infer the relation between the statistical indicators and learner collaboration. The decision tree algorithms classify the given dataset instances according to the students' collaboration label, which corresponds to their level of collaboration. These algorithms provide a logic tree, which shows the dataset attributes used in the classification process (i.e., those that were more discriminatory). As we know the logic and theoretical difficulties (what the collaboration is, how to collaborate, what indicates the best way of collaboration [14]) of finding a model describing learner collaboration, we did not look for a model, which indicated how people collaborate. We looked for an estimate of indicators, which describe the collaboration in some way. This estimation is provided by decision tree algorithms, which link a model with the dataset attributes. Other methods like Bagging [6], whose approach is similar to the method being described here, improve the learnt model. As we did not look for the best model learned, we did not use those approaches. The decision tree algorithms are very sensitive to small changes in the instances. Accordingly, all dataset attributes should be used in the logic tree of some decision tree algorithm. However, the attributes that were most related to the collaboration should appear more than others and thus the machine learning algorithm bias is removed or alleviated.

The statistical indicators considered in datasets were as follows. We selected the statistical indicators to describe learner initiative, activity, constancy and regularity, and their acknowledgement by their fellow students, which are suitable for collaboration according to [22]). The statistical indicators considered in datasets were: number of threads or conversations that the learner started (num_thrd), and their average, square variance and the number of threads divided by their variance; the number of messages sent (num_msg), and their average, square variance and the number of messages divided by their variance; the number of replies in the thread started by the user (num_reply_thrd), and divided by the number of user threads; the number of replies to messages sent by the user (num_reply_msg), and divided by the number of user messages. The indicator number of threads started and its associated indicators are related to learner initiative. The square variance of the indicator number of threads is related to the constancy of the initiative. The indicator number of messages sent and its associated indicators are related to learner activity and constancy of activity. The indicator number of replies to messages sent and its associated indicators are related to the activity caused by the learner.

The statistical indicators are grouped into datasets expressed in tables where each row refers to the twelve statistical indicators of a student's interactions. Datasets were constructed with the indicator values for each academic year.

The doubt arose as to whether it was necessary to filter the datasets as some teams participated little in the forums because of coordination problems or they used other means of communication. Thus other datasets were created with the same data but without the students in the teams with little interaction. In other words, the students in teams with little activity were eliminated from the original dataset. The criterion for filtering was: eliminating students from a team, whose interaction was below half the average interaction of all the teams. During all the collaboration period these team members sent an average of 65 messages in the academic year 2006/2007, 73 in the academic year 2007/2008 and 87 in 2008/2009. In the academic year 2006-07 12 teams were filtered, 11 in the academic year 2007-08, and 8 in the academic year 2008-09.

The machine learning algorithms were trained to provide the validity of the different indicators. Then the datasets were labeled with a list of learner collaboration levels. An expert, who read the forums messages of each team and gave one value for the collaboration level to each learner in comparison with the other team members, supplied this list. The expert used a scale of 9 values (1 very collaborative, 9 not very collaborative, although the label "9" was used only to label students who did not send any messages).

Finally 2 dataset were built with the students' statistical indicators of every academic year. Thus, the non-filtered datasets were D-I-06-07 (104 labeled instances), D-I-07-08 (124 labeled instances) and D-I-08-09 (107 labeled instances), and the filtered datasets were D-II-06-07 (79 labeled instances), D-II-07-08 (97 labeled instances) and D-II-08-09 (88 labeled instances).

We needed machine learning algorithms that could classify learners according to their collaboration level. We used decision tree algorithms, because they return a logical tree, where each tree node is an attribute of the dataset. The logical tree informed us of the statistical indicator in relation to the labeled learners' collaboration. Instead of choosing the best learning algorithm for a given dataset, we experimented with several. There was no criterion to say which algorithm was the most appropriate taking into account that some decision tree algorithms classify all instances correctly but the tree is very complex, and others return a simple logic tree, although the logic tree does not classify all instances correctly [21]. For this reason there was no suitable criterion to choose only one decision tree algorithm. We used the data mining software WEKA [25], which includes several decision tree algorithms. We proposed the following working method: 1) Train all possible decision tree algorithms, which return a logical tree. 2) Identify the statistical indicators used from each logical tree. 3) Counting up how many decision tree algorithms use the identified indicator in every dataset. 4) Construct a metric with the most used statistical indicators. 5) Relate the metric to the collaboration level provided by the expert.

V. Results

We trained the decision tree algorithms with the labeled datasets and counted the number of decision tree algorithms that used some statistical indicator in the logical tree. The decision tree algorithms used were: Best first decision tree, DecisionStump, Functional trees, J48, Logistic model trees, Naïve Bayes tree, Random tree, REPTree, Simple Cart. Table I shows these results.

TABLE I. NUMBER OF DECISION TREE ALGORITHMS THAT USED SOME STATISTICAL INDICATORS IN EVERY DATASET.

	D-I-06-07	**D-II-06-07**	**D-I-07-08**	**D-II-07-08**	**D-I-08-09**	**D-II-08-09**
Num_thrd	4	3	3	2	**7**	**8**
Med_thrd	2	2	3	2	3	4
Var_thrd	4	3	4	3	4	5
Level_thrd	**5**	4	4	4	5	4
Num_msg	**5**	4	**5**	4	2	5
Med_msg	2	2	2	1	3	4
Var_msg	4	4	4	3	5	5
Level_msg	4	**5**	4	**5**	4	**8**
Num_reply_thrd	3	3	3	2	4	4
Med_reply_thrd	2	3	4	4	2	5
Num_reply_msg	4	3	**5**	**5**	3	**8**
Med_reply_msg	3	3	**5**	**5**	5	5
No. algorithms used	6	6	7	7	7	9

Each column represents the number of decision tree algorithms that used the statistical indicator (first column) in their logical tree with each dataset (first row), and therefore the importance of a given statistical indicator in relation to collaboration. For example, four (see column 2 and row 2 in Table I) decision tree algorithms (J48, Logistic model trees, Random tree, REPTree), which were trained with the dataset D-I-06-07 (2006-07 dataset without filtering non-active teams), used the statistical indicator "num_thrd" in their logical trees. However seven decision tree algorithms, which were trained with dataset D-I-08-09 (2008-09 dataset without filtering non-active teams), used the statistical indicator "num_thrd". We note that some decision tree algorithms did not return any logical tree in some cases, but in other cases they returned the logical tree. This is the reason for the last row in the table above. Slight differences can be observed between the unfiltered datasets of teams with little activity (D-I-XX-YY) and the filtered datasets of teams with little activity (D-II-XX-YY). The differences are due to the sensitivity of these algorithms to small changes in the data provided [20]. Adding the filtered datasets, in this instance, the number of trials is increased, so each decision tree algorithm's bias can be reduced.

To better identify the relationship between the indicators and collaboration, we added up the number of uses for each statistical indicator. As the number of decision tree algorithms were different depending on the datasets (see the last row of the Table I), we weighted the addition with two criteria: I) Each value in the table above is divided by the maximum value in the column and then the values are added up in each row. II) Each value in the table above is divided by the number of algorithms used (the value of the last row) and then the values in each row are added up. The results are shown in Table II.

TABLE II. WEIGHTED ADDITIONS ACCORDING TO CRITERIA TO IDENTIFY THE MOST RELATED INDICATORS TO COLLABORATION.

	Addition I	**Addition II**
Num_thrd	4.40	3.77
Med_thrd	2.73	2.25
Var_thrd	4.00	3.29
Level_thrd	4.61	3.80
Num_msg	4.51	3.63
Med_msg	2.33	1.97
Var_msg	4.34	3.60
Level_msg	5.17	4.25
Num_reply_thrd	3.27	2.73
Med_reply_thrd	3.51	2.82
Num_reply_msg	4.83	3.91
Med_reply_msg	4.54	3.70

From the table above we conclude that the statistical indicators most related to the collaboration level are: **level_msg**, **num_reply_msg** and **level_thrd**. With these statistical indicators we have created this metric:

$$\text{Metric I} = \alpha(\text{level\_msg}/\max(\text{level\_msg})) + \beta(\text{num\_reply\_msg}/\max(\text{num\_reply\_msg})) + \gamma(\text{level\_thrd}/\max(\text{level\_thrd}))$$

We note that the statistical indicators are normalized. The possible values of the statistical indicators are between 1 and 0. We normalize because the "level_msg" is always higher than "num_reply_msg" and "level_thrd" values and the effect of the "level_msg" on the metric would be too high. We introduced the constants α, β and γ to weight the metric. In this experiment we did not weight the metric, thus $\alpha, \beta, \gamma = 1$.

Finally, we related the metric to the collaboration level list. We calculated the value of the metric in each dataset. Then we grouped the instances according to their collaboration level, which was provided by the expert, and we measured the average metric of each group. The results are shown in Table III.

TABLE III. METRIC I AVERAGES FOR EACH COLLABORATION LEVEL IN EACH DATASET.

Level	D-I-06-07	D-II-06-07	D-I-07-08	D-II-07-08	D-I-08-09	D-II-08-09
1			1.03			
2	1.89	2.10	1.89	1.64	1.83	1.83
3	1.61	1.68	1.53	1.58	1.50	1.50
4	1.37	1.54	1.50	1.49	1.27	1.33
5	1.08	1.30	1.34	1.43	0.98	1.02
6	0.78	1.21	0.95	0.97	0.93	1.12
7	0.69	1.07	0.86	0.86	0.54	
8	0.60		1.22	1.27	0.95	0.95

We note that each level has a different metric value and this value increases when collaboration increases. Only the metric predictive value is wrong in the extreme levels (1, 7 or 8), where the number of instances was small. There are cells without value, because there was no instance with this collaboration level. In other words, higher values in the student's metric mean that s/he is more collaborative than others, and lower values (but not the lowest) in the student's metric mean that s/he is less collaborative. As this metric behavior is repeated in all the datasets, it can be suggested that the metrics are related to student collaboration, so the approach was validated.

VI. CONCLUSION AND FUTURE WORK

In this paper we have proposed a data mining approach to rank learners according to their collaboration. We think that the data mining method covers the objectives needed to improve the collaboration process. The objectives are: to obtain information on learner collaboration just after the collaboration interactions have finished and to be domain independent. These objectives are needed to apply the data mining method to other open collaboration learning environments and help learners in collaboration process management.

This research focused on obtaining information on the collaboration process using the statistical indicators of learner interaction in forums. As the statistics from the forums do not give any semantic information, the statistical indicators are domain independent. We propose that the statistical indicators are related to the initiative, activity and constancy of learners and the activity caused by learners. Our first objective was to build a metric, which represented learner collaboration mathematically. This metric had to collect some proposed statistical indicators. We needed to know the relation between the statistical indicators and collaboration. We used decision tree algorithms to establish this relation. An expert's analysis labeled the statistical indicator instances of learner interaction according to learner collaboration. Thus, the decision tree algorithms relate the statistical indicator to collaboration.

To validate the approach the experimentation of his research took place over three consecutive academic years 2006-07, 2007-08 and 2008-09, and over 100 students took part in the collaborative learning experience each year (125 in 2006-07, 140 in 2007-08 and, 115 in 2008-09). We built datasets with the statistical indicators of learner interactions in forums. At the same time, an expert labeled each learner according to his/her collaboration level. The labeled datasets obtained were used to train decision tree algorithms. The logical tree algorithm offered those statistical indicators that are used to learn the classification according to collaboration. We used the statistical indicators, which were most related to collaboration, to build a metric. Finally, we checked that the metric was associated with collaboration.

We have shown that the metric proposed establishes a mathematical relation with collaboration. Therefore, learners can be ranked automatically according to their collaboration while they are in the collaboration process. This metric can be used during the collaboration process in all LMSs or collaborative environments that use forums as the main communication mean. We have observed (see Table 3) the metric represents approximately the learners' collaboration. High values in the metric mean very collaborative learners. We have checked that this behavior is equal in all datasets of the research. Thus we argue the metric I can represents the learners' collaboration in future collaborative learning experiences, and the metric can be built easily, because the metric is a mathematical relation along some statistical indicators of interactions in forums. In addition, thanks to the flexible and general nature of the approach it can be transferred to other LMSs or collaborative environments.

Moreover in terms of the metric the method informs regularity and frequently about the learners' collaboration, which is needed to ensure that the collaborative learning happens [14] and gives information on metacognitive characteristics related to their collaboration, which helps learners to improve the collaboration process [10], and from that it is expected to affect positively their learning process.

After this research, to measure the effect of using the ranking method in an educational environment we need to check the improvement of the collaboration learning in comparison to other learning experiences without the ranking method. We have considered this issue and we researched other inferring methods [1]. We obtained positive results and deduced that an inferring method on collaboration improved the collaboration process management. We have to research this issue with the ranking method in future collaborative learning experiences. Other open issue is if the current inferring method can be improved. We have researched other machine learning methods to obtain the same objectives. In [1] we described our research when we used clustering algorithms to classify learners in spite of decision tree algorithms to rank learners. Both approaches have advantages and disadvantages. We must compare both inferring methods with the same data. However since the goal of the approach is to support learners' collaboration rather than applying the more precise machine learning approach we do not expect significance variations on the method. Another related open issue is the metric itself. In this paper the results were obtained when the metric constants α, ß, γ = 1, without weighting the metric. We are currently researching with weighted metrics where the constants (α, ß, γ) have different values and from that we will be able to compare the results between weighted metrics and non-weighted metrics in order to identify which one obtains better results.

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Session 04F Area 3: Degree Programs and Curricula

The New Degree in Materials Engineering at the Technical University of Madrid (UPM)

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Use of Advanced Technologies in a RF and Microwave Engineering Course

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Natural Sciences in the Information Society - First Experiences

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The New Degree in Materials Engineering at the Technical University of Madrid (UPM)

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Abstract — **The Technical University of Madrid (UPM) is pioneering the introduction in Spain of a new Degree in Materials Engineering, with a four-year duration, accessed directly from the baccalaureate-level studies. The materials engineers from the UPM will be prepared to meet the challenges not only in the field of structural materials, but also in functional materials and biomaterials. With the objective of enhancing student exchange programmes, the third year of studies will be taught entirely in English.**

Keywords: Materials Engineering, Degree Programmes

I. Introduction

The ability to manipulate, understand and use innovatively materials is an important measure of the sophistication of a civilisation. Our lives are enhanced and restricted by our relationship and ability to use materials effectively.

Materials engineering is an interdisciplinary field that studies the relationship among the structure of materials at atomic or molecular scales, their macroscopic properties, their processing and their applications. Materials scientists and engineers help to develop the materials required for new products, find better lower-cost manufacturing routes, and enhance the performance of existing materials. They consider the environmental impact and sustainability of their products. They discover how to optimise the selection of materials and create sophisticated databases from which properties and service behaviour can be predicted.

The study of materials engineering has for many decades been established across the economically-developed world. The academic study of materials encompasses aspects of the physical sciences and of engineering, with two central themes: the link between structure and chemical, physical and mechanical properties; and how control of microstructure through processing can be used to optimise engineering performance. The range of programmes to which this benchmark statement applies is diverse and extends from science-based to engineering-based programmes.

In this paper, the new Degree in Materials Engineering that the Technical University of Madrid (UPM) has started in 2009 is described. First, the scientific and engineering related knowledge and skills of Materials Engineering discipline are analysed. After that, characteristics of the Materials Engineering programmes at present in Spain and the rest of the world are revised, and finally the main features of the new Degree at the UPM are exposed.

II. The Materials Engineering Discipline

Historians have categorised the early ages of humankind in accordance with the materials utilised, with the emergence of the terms Stone, Bronze and Iron Age. In more contemporary times both concrete and steel have arrived, with the latter material being at the base of the industrial revolution.

The field of materials engineering began to be considered as a discipline in itself around the mid-1960s. At first, many materials science departments were named metallurgy departments and focussed their research and teaching on metals.

Yet if there were a material that could be said to have characterised the second half of the twentieth century, such a material would be silicon. Silicon is the *steel* of the semiconductor industry [1]. As steel allowed the industrial revolution to transform the more advanced countries of the time, silicon has provided the support that has enabled information technology to transform the contemporary world.

Developments in silicon have shown that materials engineering was not merely the legacy of metallurgy or even that of structural materials. There is no doubt that the field of structural materials engineering has a significant part to play in the aerospace, automotive and energy sectors. But, in addition, the area functional materials, those without a resistance function, cannot be overlooked, in particular those linked with the area of electronics (the next revolution in information technology will use light to transport and amplify information through photonic materials), as well as in the production of *clean* energy (materials for solar cells and fuel cells will be essential for the development of such *clean* energies) [1].

However, equally important is the development of biomaterials in the assessment, cure and replacement of organs and tissue. The dawn of a new age has been reached, one which has been termed the age of biomimetic materials. Materials will be developed that are able to “mimic” the properties and processing of biological materials. Previously little known nouns such as hierarchical microstructure and self-assembly will serve as basic terminology for the materials of the future. Furthermore, nanotechnology – applied to the field of biomaterials – is providing new approaches in the design of materials that will permit diagnostic and therapy techniques which will revolutionise healthcare.

In the 21st century, the field of materials engineering has been broadened to include every type of materials, including ceramics, polymers, semiconductors, magnetic materials, medical implant and biological materials.

III. Materials Engineering Programmes at Present

With significant media attention focussed on biotechnology and nanotechnology, in recent years materials engineering has been propelled to the forefront at many universities.

The study of materials engineering has for many decades been established across the economically-developed world, in particular in the member states of the European Union, in the United States and Japan [2]. In these countries, the degree in materials engineering – undertaken by students who have completed baccalaureate studies – provides graduates with a high level of professional competence throughout its four-year duration.

The preparation of the syllabus of the new Degree in Materials Engineering at the UPM has involved consultation with more that 70 European institutions and more that 40 private and state universities in the United States [3]. In the latter, a country which boasts more than 20,000 qualified materials engineers, these professionals occupy a leading place in the annual salary ranking that spans the different fields of engineering [4].

In comparison with other developed countries, in Spain the materials engineering degree course is a relatively recent programme. The UPM was the first institution to introduce an upper-level degree in the field in 1995 [3]. To be accepted to the course a prerequisite of three years of studies in another area of engineering was set. The orientation of the course was to structural materials, evolving from metallurgical engineering. At present, this upper-level degree is taught in another 14 universities across Spain. Since the first students of engineering materials graduated in 1998, more than 10 years of running the course have allowed alumni to access excellent career opportunities in all fields of engineering.

IV. The New Degree at the UPM

With the arrival of the Bologna Process and reform and adaptation of higher education in Europe, in Spain the UPM is once again a pioneer institution in the introduction of a new post-baccalaureate, four-year degree course in materials engineering [5].

The degree programme is measured in accordance with the credits awarded by the new European Credit Transfer and Accumulation System (ECTS). Considering one ECTS credit to involve 25-30 hours of study, the new Degree in Materials Engineering will entail 240 such credits, structured over four academic years (eight semesters) of 60 credits each one (30 credits per semester). Under such a structure a final-year dissertation or end-of-degree project (equivalent to 12 credits) will be undertaken.

The objective of the new programme is to provide engineering graduates with an interdisciplinary technical preparation, seeing them equipped to work with any type of material (biological, ceramic, metallic and polymer), and primed with a high capacity to adapt, both in terms of research and in development and innovation. In a rapidly-evolving world, the materials engineer will have to know how to model (to extract the characteristic parameters of a given situation), design (both new material and structural elements) and possess multidisciplinary knowledge.

The course involves a forward-looking curriculum in which students acquire knowledge of the three main branches of the field of materials: traditional structural materials, but also functional materials (semi, dielectric, optical conducting and magnetic materials used to create integrated circuits, storage media, sensors and other devices) and biomaterials (materials that interact with biological systems; materials of biological origin; and biomimetics) [5].

Basic skills

On account of its content and orientation, the Degree in Materials Engineering will be attached to the area of knowledge of Engineering and Architecture, including a total of 60 ECTS credits of basic subjects of such an area (see, Table I). The primary topics include acquisition of knowledge and skills in mathematics, chemistry and physics, as well as biology in order to support aspects of biomaterials programmes. Economy and Industrial Process Management has also been included. These subjects will be studied in the first two years of the programme.

TABLE I. Basic Subjects

Subject	ECTS
MATHEMATIC	12
ELECTRICITY AND MAGNETISM	6
ESSENTIAL CHEMISTRY	6
MECHANICS	6
THERMODYNAMICS	6
BIOLOGY	6
QUANTUM PHYSICS	6
SURFACE CHEMISTRY	6
ECONOMICS AND INDUSTRIAL PROCESS MANAGEMENT	6

Clearly, skills in maths and physics are a requirement for filling the pipeline of future engineers. It may seem logical to teach the foundational concepts for an engineering problem first, and only then introduce the engineering task. In many ways, the traditional engineering curriculum follows this model. However, the “basic first” approach is a poor instructional strategy at present [6].

Several studies have shown that it is expected the number of students who enter engineering programmes in college is projected to drop. To address this problem, new motivators are urgently needed, and engineering design activities is one of them. Introducing engineering problems from the first courses could help to create a powerful motivation for learning relevant science, and improve the interest in engineering careers.

In the new degree programme efforts have been made – from the very first semester – to involve students in working with the nucleus of materials discipline: that is to say, in knowing how to associate the structure of materials with their properties (Table II). Property and structural synthesis is carried out as early as possible in the programme, which is something that has a bearing both on the design of the material and on that of the structural element.

TABLE II. SUBJECTS INTRODUCING PROPERTIES-STRUCTURE DESIGN ACTIVITIES

Subject	Semester Schedule
STRUCTURE OF MATERIALS I	1st
STRUCTURE OF MATERIALS II	2nd
METALLIC MATERIALS	2nd
CERAMIC MATERIALS	3rd
POLYMER MATERIALS	3rd
SOFT MATERIALS	3rd

General and transversal skills

General (or transversal) skills identify shared attributes (in any degree course) which are considered to be of importance, whether by graduates or employers. Such general skills are distributed among three large groups:

- IT skills (use of information and communication technology)
- Communication and interpersonal skills (oral and written communication, organisational capacity, ability to work in a team, leadership skills, capacity to work in an interdisciplinary manner, ability to take on responsibility, and professional ethics).
- English language skills

All such skill sets, including the English language, will be taught and graded (as there will not be a specific module to cover them) in a horizontal manner, shared between all the subjects. Specifically, teaching in the English language will be deemed a priority, given its lingua franca position not only in science and technology but also in business and economic development. Consequently, the third year of teaching will take place entirely in English.

Itinerary: Specialties

Training in materials engineering requires a multidisciplinary and polyvalent approach, in the sense that the graduate will learn the foundations and applications of materials in three extensive fields: material structures, functional materials and life-science materials. Consequently, the subjects of the syllabus have been structured in a way that these three areas appear in obligatory study, both in their most fundamental aspects and in their applications, covering the necessary study needs of all graduates.

However, in order to address the complexity and specialisation of the three above mentioned areas, the syllabus will involve a specific approach, through three blocks of optional subjects taken mainly in the fourth year. Each such block marks a well-defined itinerary under which students will have to choose five subjects of a total of 24 ECTS credits. The three blocks are described in Tables III, IV and V:

TABLE III. ITINERARY: STRUCTURAL MATERIALS

Subject	ECTS
OBTAINING MATERIALS	6
SAPHE PROCESSING	5
MATERIALS ANALYSIS AND TESTING	5
JOINING TECHNIQUES	4
METALLIC MATERIALS III	4
BUILDING MATERIALS	4

TABLE IV. ITINERARY: FUNCTIONAL MATERIALS

Subject	ECTS
WORKSHOP ON FUNCTIONAL MATERIALS: STRUCTURAL	6
ADVANCED MATERIALS FOR OPTOELECTRONICS	5
ADVANCED MATERIALS FOR MICROELECTRONICS	5
WORKSHOP ON FUNCTIONAL MATERIALS: ELECTRONICS	4
WORKSHOP ON FUNCTIONAL MATERIALS: OPTICS	4

TABLE V. ITINERARY: MATERIALS FOR LIFE SCIENCES

Subject	ECTS
BIOMIMETICS	6
BIOMECHANICS	5
BIOSENSORS	5
ENGINEERING OF CELL MATERIAL	4
TISSUE ENGINEERING	4
WORKSHOP ON BIOLOGICAL MATERIALS AND BIOMATERIALS	4

Exchange programmes with other institutions

One of the primary objectives of the European Higher Education Area (EHEA) is to open education systems to free movement of students. In this sense, a primary objective considered for the new degree has been that of enhancing student exchange programmes with other European higher education institutions.

The third and fourth years of the new Degree have been open to exchange programmes, and specially important is that the third year will be taught entirely in English (Tables VI and VII).

TABLE VI. SUBJECTS TAUGHT IN ENGLISH IN THE FIRST SEMESTER (SEPTEMBER-JANUARY)

Subject	ECTS
MECHANICAL BEHAVIOUR OF MATERIALS III	6
PROPERTIES OF MATERIALS	6
COMPOSITE MATERIALS	6
NUMERICAL SIMULATION	6
OBTAINING MATERIALS	6
WORKSHOP ON FUNCTIONAL MATERIALS: STRUCTURE	6
BIOMIMETICS	6

TABLE VII. SUBJECTS TAUGHT IN ENGLISH IN THE SECOND SEMESTER (FEBRUARY-JUNE)

Subject	ECTS
QUALITY AND QUALITY MANAGEMENT	6
MECHANICAL BEHAVIOUR OF MATERIALS	6
NANOTECHNOLOGY	6
SURFACE ENGINERRING	6
RECYCLING OF MATERIALS	6

V. CONCLUSIONS

New materials have played an essential part in providing technology needed for scientific development, which has in turn brought great benefits to society. For this reason, empowering students in materials science and engineering is one of the paramount long-term investments that can be made in the technological future of a nation.

The first lectures of the new Degree in Materials Engineering at the UPM commenced in September of the academic year 2009-10, with the course being 100% subscribed.

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Use of Advanced Technologies in a RF and Microwave Engineering Course

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***Abstract*-- In RF and Microwave Engineering course, usually students struggle to build connections between the theory they have learned and practical applications in the laboratory. The laboratory applications are usually very limited for hands on experience since the high cost and maintenance requirements of the equipment. Additionally, new engineers need to know how to use at least one engineering design tool in order to practice designing RF components, circuits, or antennas. In this study, a curriculum model including recent developments and technologies in the RF and Microwave Engineering field by addressing above problems of the course is proposed. This study covers the description of the content of theoretical and hands on applications, the integration model of the technological tools into the proposed curriculum, and the instructional approaches used in the new course design which covers the use of a remote laboratory environment, Concept Maps and an engineering design tool. The course is structured with a balance between theory and laboratory, including remote and in lab measurement experiments as well as modeling and designing microwave components by means of computer tools and design fabrication. The newly designed course is implemented at the Atilim University. The first semester implementation shows promising results.**

Index Terms—RF and Microwave engineering course, curriculum design, remote laboratory, simulation tools

I. INTRODUCTION

Advances in the telecommunications industry and the widespread deployment of wireless network services have affected the career programs related to high frequency technology. These developments have also forced practicing engineers, computer specialists, and managers to re-educate themselves in the area of telecom/radio-communications technology [1], [2]. Parallel to these developments, a report by an industry/education partnership (Global Wireless Education Consortium-GWEC) involving more than 30 universities and 9 large companies in the wireless sector in the USA has identified new requirements for such professionals as well as noted a lack of Radio Frequency (RF) specialists [3]. Accordingly, several related educational programs have begun offering courses covering electromagnetic, RF, antenna, and microwave concepts, which are important components of any Electrical and Electronics Engineering (EE) and computer-related educational curriculum [4] and technical colleges, which are usually supported by hands-on experimental environments. For example, a remote laboratory on frequency modulation experiment principles [5], a face-to-face laboratory implementation in the field of antennas [6] and RF-microwaves [7], an RF hardware design laboratory with project oriented approaches [8], and wireless information networks [9] have been integrated in the curriculum of these courses. As Cassara [9] summarizes, some of these implementations exist that generally focus on wireless networks, radio frequency-microwaves, antennas, radar or optical communications. These implementations and studies show the recognition of the importance of these topics in the educational arena.

Parallel to these developments simulation (and CAD) applications are also started to be used as a critical and efficient tool on these courses. Additionally, Web-based and Web-assisted education alternatives are a new paradigm that is started to play an increasingly significant role in the instructional design efforts in these fields [4]. Accordingly, in order to prepare engineers satisfying the requirements of the industry, new approaches need to be reflected and emphasized in the curriculum of these courses.

In this study, the current situation and problems of electromagnetic, RF, and microwave courses offered at Atilim University are discussed first. In order to address the identified problems, this study proposes a curriculum model that reflects recent developments and technologies such as remote laboratory environments, simulation tools, and mind map graphical representations. This study covers a description of the content of theoretical and hands-on applications, an integration model of the technological tools into the proposed curriculum, and the instructional approaches that are used in the new course design. The newly designed course has been applied during one semester in the EE education program at Atilim University. This study also describes how the newly designed course is offered, as well as the problems faced and gains achieved during this course.

II. COURSE DESCRIPTION

As juniors, students with an EE major at Atilim University take one semester-long required RF and Microwave Engineering course. The aim of the course is to prepare the students for their future professional careers in RF and Microwave Engineering and for the sequence of senior courses, such as Antennas and Propagation, RF Microelectronics and Optical Communication Systems and Design Projects. These courses are offered as technical elective courses in the curriculum of the EE program of the university. The course is structured with a balance between theory and laboratory, including remote and in lab measurement and evaluation, modeling and designing microwave components by means of computer–aided design (CAD), and fabricating.

A. Course Content

The course is designed as an introduction to RF and Microwave (MW) systems. The following concepts are covered in this course: analysis of transmission lines and waveguides, the Smith chart, scattering parameters and matching networks, LC networks, single and double stub tuning using the Smith chart, RF and microwave passive components and system parameters, high frequency configurations of filters and amplifiers, PCB realization of RF and Microwave circuits, microstrip lines, and RF, Microwave, and Antenna design tools and measurement techniques.

B. Course Objectives

In this course, students should acquire the following skills and be able to:

- state the applications of electromagnetic spectrum above 300MHz frequency band;
- identify wave propagation on transmission lines and expand it to include microstrip structures;
- identify the fundamentals of transmission line systems, radio frequency (RF) and microwave components, sub-systems, and technology;
- operate tools and equipment used in the design and analysis of RF and Microwave components and sub-systems,
- design microwave components such as a microstrip line, microwave filters and single-stage microwave transistor amplifiers.

C. Laboratory Activities

Laboratory experience is an important part of an electrical engineering (EE) education. As shown in recent Internet-based remote and virtual laboratory studies, effective learning in EE education can only be achieved by approaches that combine theoretical courses with laboratory work where the learner can practice as necessary [1]. Laboratory experiments are usually performed as demonstrations on the following subjects: scattering parameters measurement, VSWR measurements and transmission line impedance, power measurements, and antennas measurement.

D. Problems with the Course

The course instructors face with several problems in this course. We can group these problems under three main headings: Laboratory hands-on experience problems, implementation of new technological tools in these courses and implementation of new instructional approaches used in these courses.

Problem 1: Since the only chance to provide the laboratory experiments by means of demonstrations in the laboratory, it is usually not clear for the students that what they have learned and how to relate it with the theory that they learn during the classroom instructions.

Problem 2: The instructor usually group students into 8-10 for each demonstration section. However this number is also still high for the demonstration sections and it is usually not possible to organize smaller student groups because of the high number of students enrolling this course.

Problem 3: The instructors also face with some maintenance problems in the laboratory since students accidentally broke some parts of the equipment. For example, once a student has broken while connecting 2.4mm to SMA adaptor of the Vector Network Analyzer (VNA). The instructor had to order this part from the company and it took three months to fix the problem. Accordingly, the instructor could not be able to use this port of the VNA in that year and only be able to show measuring S11 parameter.

Problem 4: There is a need for implementation of new technological tools in these courses. It is very important for the industrial organizations that the new engineers should know how to use at least one engineering design tool in order to practice on designing RF components, circuits or antennas. For example, our graduates are usually getting a job offer easily and becoming more competitive if they have experience on the design tools for RF, microwave or antenna. Additionally, the simulation tools such as CAD, help them to better figure out and experience the real-world industrial applications based on the theories that they have learned in the classroom. Introducing a simulation tool in such introduction courses also help students to better prepared for the advanced level courses such as RF and microwave circuit or antenna design and design project courses. In these courses they have a quick start without loosing time on learning and practicing on the simulation tools.

Problem 5: There is a need for implementation of new instructional approaches used in these courses. The instructors of these courses should provide some instructional approaches for building relationships between the theory and practical content of the course. Otherwise, students are having problems to build this relationship by themselves and they think that some of the theoretical content is not applied in theory. As a result, students usually forget the theoretical information because of the loss of connection with the theory and practice components of the course. During the laboratory hours, students always complain about finding related theory on a specific experiment that they are working on and performing and usually their intension is on thinking that the lecture instruction (theory of the course) is not related with the experiments that they are performing. On the other hand, students' learning expectation differ each other. Some students prefer to reach directly to the content that they are searching for, while others prefer to study the content from the beginning and then continue the experiments. Some of them prefer the graphical representations while the other prefer to read the text [10]. Accordingly, the instructors may have problems offering lectures that meet the needs and expectations of the students.

III. Background of the Study

In order to solve the above problems, we have researched the literature to investigate appropriate solutions. Some studies that address the problems faced in this course are summarized in this section. In traditional ways, the laboratory applications of these courses are offered by means of face-to-face training in particular laboratories. Usually, even for ideal cases, face-to-face laboratory applications in these courses have some limitations for both the instructor and the learner [11]. For example, offering such courses requires a large number of educators and supporting personnel as well as high setup and maintenance costs for some EE laboratories (such as those covering radio frequency and microwave techniques) [5]. If an open laboratory environment is not provided, students are restricted to a specific schedule and location for a particular course and are not be able to repeat the experiments as often as they wish or possibly need. Students also tend to have very limited opportunities to analyze the experimental data mathematically: usually the measurement device itself is unable to handle a large amount of data. In the absence of time constraints, students have the opportunity to process experimental data by using powerful software analysis tools, thus obtaining a clearer notion of the functionality of a certain device or setup.

Recent developments in Internet-based services also encourage training and educational organizations to attempt e-learning models. Nowadays, educational and training organizations, particularly universities, are frequently using Internet technologies to enhance and supplement traditional face-to-face education. For example remote laboratory platforms enable learners to access physical instruments at a distant location and perform experiments remotely on the Internet [12]–[15]. Hence, a remote laboratory application in the RF domain seems to be a very critical tool in order to improve and support current educational environments.

Additionally, computer simulations have been used in the curriculum of some EE courses such as electromagnetics, RF, microwave, and millimeter-wave areas [16], [17]. As Gupta et al. state, these simulators encourage building realistic design examples, verification of these designs, evaluation of the effects of real-life parameters on circuit characteristics before investing in the actual fabrication of the circuits, and building case studies that bridge the gap between classroom instruction of microwaves and the practice of microwaves in industry [4]. According to Gupta et al., for the first time in the history of microwave education, the aim of providing classroom instruction that is 100% relevant to the practice in industry is becoming possible [4].

On the other hand, concept maps are the tools used to build relationships among concepts. These tools have been used in educational environments to better connect the relationships among theory and practice as well as among other concepts covered in a course. These tools also help the learners build relationships between previous knowledge and newly introduced concepts, encouraging meaningful learning rather than rote learning (memorizing concepts, no relationship to previous learning) [18].

IV. Newly Designed Course

To improve the course, new approaches have been proposed for the laboratory and theoretical parts. This section summarizes the proposed curriculum for this course.

A. Laboratory

In new course design, laboratory session is supported by Remote RF laboratory [12]. In this environment for teaching how to use VNA, an electronic performance support system (EPSS) tool is used [19], [20]. Remote experiments provide fundamental knowledge in electromagnetic wave propagation, knowledge about the analytical and graphical methods used in deduction of formulas used in microwaves, the ability to make correlations between the physical phenomena (what is happening and which are the causes) and the ability to handle high complexity measurement devices (e.g. VNA). European Remote Radio Laboratory (ERRL) provides RF and microwave remote experiments (http://errlmoodle.atilim.edu.tr/).

Implementation of Computer Aided Design Program (CAD)- Additionally, the new course curriculum is enriched with the applications on Computer Aided Design Program (CAD) and The AWR® Design Environment (donated by AWR Corporation) experiments. Laboratory hours include design tools to be used in the design, fabrication and analysis of RF and Microwave components. The students, after learning how to use Microwave CAD program step by step asked to design RF microwave filter for a substrate and design requirements given by the course instructor. Selected filters whose have best properties (not all of them) are fabricated in our laboratory by using PCB prototyping system, LPKF Promat C100/HF. Fabricated RF filters are measured by using VNA and analyzed.

Laboratory Applications Design Of the New Course

First week, laboratory equipment' are introduced to the students in the Remote Lab environment. For this purpose, an electronic performance system (EPSS) tool is used which provides just in time training for the users by providing the instruction according to the user needs and expectations [19], [20].

Second week, the students learn how to use RF Remote Lab website in laboratory hours. Now, the students are ready to use laboratory at anytime and anywhere without guidance .

Students freely perform the following remote lab experiments any time and any where according to their preferences:

Remote Experiment 1: Measurement of Scattering Parameters of Open, Short and Match load. This experiment is developed in order to familiarize users with control panel of VNA, fundamental principles of VNA. Furthermore, they can do basic measurements with VNA and calibrate of VNA, and observe SWR and impedance measurements with VNA. Figure 1 shows the actual physical laboratory setup for the experiment.

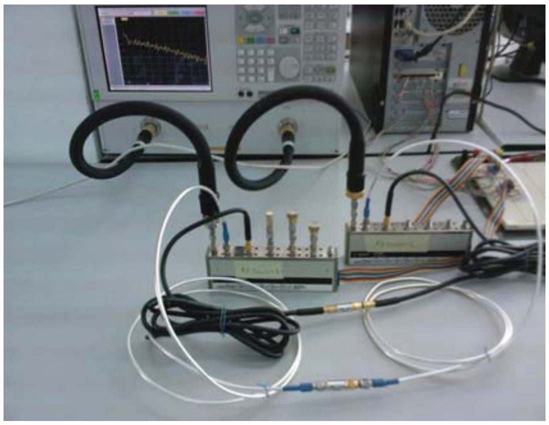

Figure 1. Setup for Measurement of scattering parameters of open, short and match load experiment

In this experiment, fundamental functions and controls of AGILENT's 8363B VNA is examined. Open load, short load and 50 ohm load are used as DUT (Device Under Test). Calibration procedures are defined, as well. VNA are used by the users to validate concepts like VSWR, reflection, and impedance matching by means of Smith Chart. Users can observe differences between theory and experiments since a remote laboratory works with real physical effects.

Following three weeks (3-5th weeks), the students learn how to use CAD program and to design simple microwave components :

AWR Experiment 1: Design a Simple RC Filter to be familiar AWR environment and to understand how to simulate, create graphs and analyze a circuit in AWR.

AWR Experiment 2: Transmission Line and Microstrip Line Analysis to study the behavior of an ideal transmission line (TL) at various lengths , to calculate width and length of microstrip line by using AWR and to gain an ability to use some AWR tools , to store the information of the substrate material used in the microstrip line, to solidify students understanding of transmission line theory and be able to design a microstrip line.

AWR Experiment 3: Design a 10-dB T-Attenuator by Using Lumped Elements in order to strengthen to simulate, create graphs and analyze a circuit in AWR, to design a passive RF component, to analyze the network behavior of multiport microwave systems.

AWR Experiment 4: Smith Chart and LC Matching Network to get familiar with the Smith Chart by plotting different impedance values and design a LC matching network, to use Smith Chart when solving transmission line problems, to analyze generator and load mismatched transmission line.

AWR Experiment 5: Single Stub Tuning to gain an ability to use some AWR tools, to improve the ability of simulate, create graphs and analyze a circuit in AWR to design a microstrip line, to use Smith Chart when solving transmission line problems, to analyze generator and load mismatched transmission line, to design single stub tuning networks in the design of microwave components and circuits

Remote Experiment 2: Measurement of Scattering Parameters of RF Filters. In this experiment, users are familiarized with the basic microwave passive elements and measurement techniques. The objective of the experiment is to observe the concepts of reflection and transmission (return loss, standing wave ratio, reflection coefficient), to measure the frequency responses and the behavior considering the direct and reflected wave of a microwave filter and insertion loss, bandwidth and out-of-band-rejection. For the experiment on measurement of scattering parameters the user must set VNA parameters such as the frequency range and number of points. One of the scattering parameters must be chosen. In this experiment, a user can view transmission characteristics of the filter and find the type of the filter (band pass, low-pass, high-pass, or not-sure), the frequency at which the minimum attenuation for the filter occurs, minimum loss and the 3dB cut-off frequency for the filter, defined as that frequency where the transmission coefficient is reduced by 3dB from the minimum attenuation.

Remote Experiment 3: Extraction of Physical Parameters of a Coaxial Medium with Vector Network Measurement is performed. When a typical calibration is processed, the measurement reference plane is moved to the very ends of the test cables. But what would happen if we had a transition (such as connector, cable, adaptor…) between the DUT and reference plane. In this experiment we perform two measurements, with transition and without transition (Fig. 2). After the measurements we decide the effect of transitions. The effect of a transition on phase and reflection coefficient (S11) is examined and phase constant (β) and relative permittivity (ε_r) are calculated by means of these measurements.

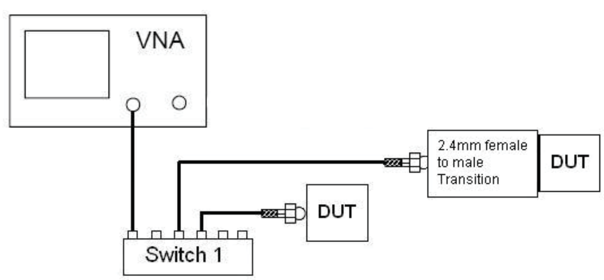

Figure 2. Remote experimental setup for extraction of physical parameters of a coaxial medium with vector network measurement experiment.

At certain frequency, phase constant (β) and relative permittivity (εr) are calculated by using the measurement results and $\lambda = \frac{2\pi}{\beta}$ $\varepsilon_r = \sqrt{\frac{\lambda_0}{\lambda}}$

During following two weeks (weeks 6 & 7), students perform the following experiments freely by using the distance laboratory environment [ERRL referans]. During this period, students are also free to use the physical laboratory environment to design any RF component.

Remote Experiment 4: RF Amplifier Measurements experiment. In this experiment basic measurement of power amplifier (Fig. 3) with VNA is performed for constant input power. Frequency characteristics are measured for different frequency values. This experiment allows the user to become familiar with the power amplifiers and their frequency band measurement with VNA. When completed, the user has an idea about characteristic such as gain, flatness, impedance, return loss etc . Vector network analyzer measurement capabilities are also improved.

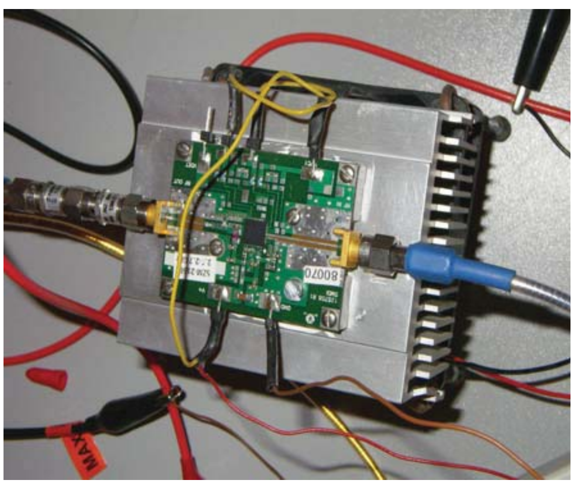

Figure 3. RF power amplifier.

Remote Experiment 5: Antenna Analysis. This experiment is focused on the measurement, of reflected-transmitted power, of input impedance vs. frequency and SWR of several antennas (Fig. 4). With this experiment various measurements on wire, horn and patch antennas are performed with the Vector network analyzer. Aims of the experiment are measurement of loss power, reflected power and transmitted power of the antennas and the SWR and the input impedance of the antenna at the certain frequency range.

Last three weeks (8-10th weeks) are reserved to the students for designing, implementation and measuring their own RF microwave filters. Students work in a team to design a filter with specifications that is provided.

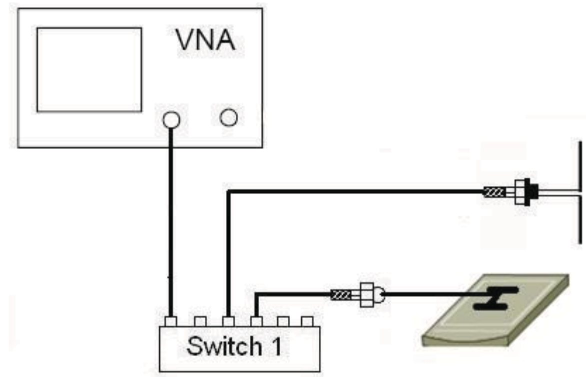

Figure 4. Remote experimental setup for antenna analysis experiment.

B. Theoretical Instruction

One of the problems of this course was building relationships between course content and laboratory applications. Accordingly, as shown in Figure 5, we have developed a concept map in order to help students develop these relationships. The map in Figure 5 shows how the relationships between the course content and laboratory experiments can be formed. The graphical represantation also helps to better visualize the possible relationships.

In this concept map experiments are connected by lines to the course content by using keywords. In this way it is expected that students will be able to build relationships between the experiments and theoretical content and analyze the experiment results accordingly. They are also able to find the theoretical details by using the search functionality of the remote laboratory environment[1].

We have applied this newly designed course for one semester at Atilim University. Students' feedback and course instructor's opinions were very positive after the implementation of the new course. They all declared that the problems that they had faced in previous years were all addressed with the new course design.

[1] http://errlmoodle.atilim.edu.tr/

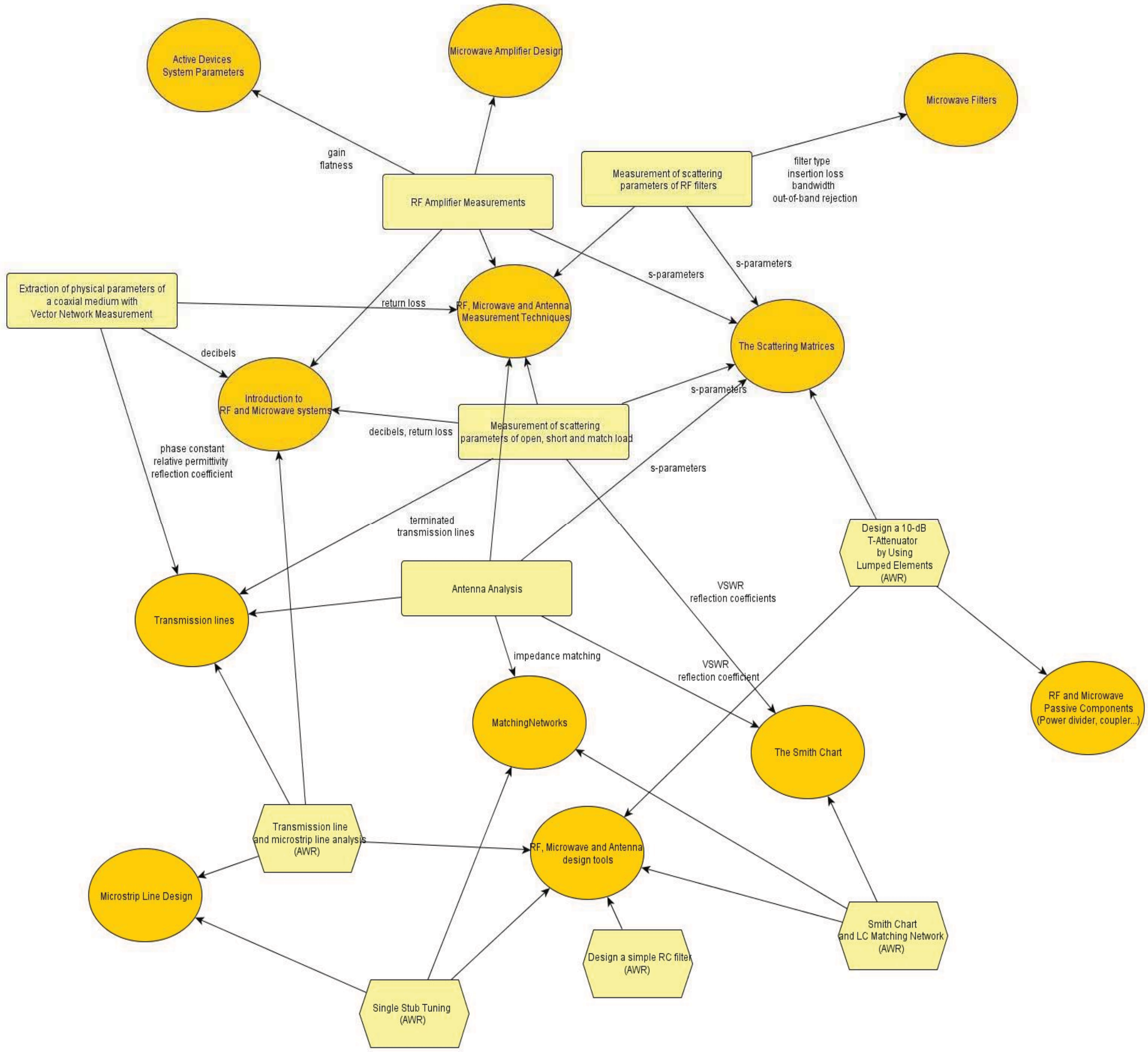

Figure 5. A Concept Map of Course Theory and Hands-on Application Activities

V. Discussions and Conclusions

In this study, we first listed the main problems of the introduction to RF and Microwave (MW) systems course. Then, in order to address these problems, we proposed a new curriculum model for both the laboratory and theoretical parts of the course. Finally, we applied the new curriculum of the laboratory activities for the course over one semester.

The course instructor believes that, because of the new approaches used in this course, instructors will have more time to extend course content and provide more experiments for the students. For example, in this semester the course instructor had time to demonstrate seven experiments that had not been studied in previous years.

The course instructor also reported that the remote laboratory environment significantly improved students' understanding of the experimental studies when compared to previous years. Additionally, since the students were better prepared to understand the background of the RF/Microwave components design, they were able to fabricate and measure the RF/Microwave component.

After taking the newly designed course, the students will not need to learn how to use the design and measurement tools featured in elective courses and design projects that follow in the sequence of the EE program at this University. These skills are expected to eliminate the need to provide repeated instructions on the usage of these tools throughout the curriculum, which allows for additional time for the instructors to perform other activities.

We believe that, in the long term, the students will receive greater numbers of job offers and their job performance will improve because they will be better prepared for industrial environments due to their exposure to the new technologies and more practical hands-on, trial-and-error type experiences.

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Internet-based Performance-centered Learning Environment for Curriculum Support (IPLECS) and its application in mLearning

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***Abstract*— IPLECS is a virtual campus platform for the development of performance-centered reusable learning materials, and its application in mLearning for educational and training purposes. The combination of performance support systems and mobile devices present both opportunities and challenges for work-based learning design.**

Keywords-* *Internet-based learning; Performance-centered learning, curriculum development.; Engeenering Education.

I. INTRODUCTION

We present two Projects financed by Socrates Agency. The first in about the curriculum development of one ' Information and Communication Systems' Master; the second one is about its application and development in mobile leaning.

Internet-based Performance-centered Learning Environment for Curriculum Support (IPLEC S) is a virtual campus platform for performance-centered reusable learning materials development, their composition and organization in performance-centered settings and their usage to support university curriculum in physic-engineering education. IPSS_EE is an integrated electronic environment, which is available via Internet and is structured to provide individualized online access to the full range of information, guidance, advice, data, images, tools and software to permit the user to perform a task with a minimum of support and intervention by others. The system has elements of performance system, elements of traditional Web-based educational programs and automatic test system. The system uses a new technology for improving students' competency and performance by providing support for processing, analysis and reflection on information and learning experience.

The idea of educational performance support system had been implemented in different European universities and training institutions within a number of pilot projects such as IPSS_EE (Internet-based Performance Support System with Educational Elements) and DIPSEIL (Distributed Internet-based Performance Support Environment for Individualized Learning), with strong positive results in students' learning. [1].

The combination of performance support systems and mobile devices present both opportunities and challenges for work-based learning design. We describe four possible mobile performance support scenarios, namely: mobile performance support courseware; industry-based mobile performance support systems; mobile social support system; and context-based performance support.

The mobile performance support courseware repackages the existing courses in which the principles of performance support are implemented. In the second scenario, industry-used mobile performance support systems become part of higher education learning and instruction. Students learn how to use them when they perform particular work-related tasks. The social support scenario explores the opportunities created by Web 2.0 technologies (micro-blogging tools such as Twitter, social bookmarking and wikis) to connect people and facilitate their collaboration. In the fourth scenario, mobile performance support is part of a blended solution of knowledge distribution rather than a primary channel for content delivery. Mobile performance support is included in a broader constructivist instructional context and used only in particular times. Within the scenarios a set of pedagogical guidelines are formulated based on a number of theories: Four Components Instructional Design Model (4 C/ID) [2]; Cognitive Apprenticeship [3]; Cognitive Flexibility Theory [4]; Cognitive Load Theory [5]; Multimedia Learning [6] ; Minimalism [7]; Design Theory of Problem Solving [8]; and Anchored Learning [9].

Learning materials in IPLECS take the format of "learning objects" (LOs), specific for the performance-centered approach and presentation. We present the conceptual model and description of so called IPSS_EE LOs and extend the IEEE LOM. Model and description of IPSS_EE LOs are useful for understanding their features, for enabling their publishing in a Web context and for enabling their reuse across different learning sessions. A new curriculum in the field of science and technology - " Information physics and communications", will be developed. Learning materials to support a complete integrated program, developed and used in a virtual performance-based learning environment will be developed. In the whole process, various competences, innovative and consolidated information and communication technologies will be used.

The main reason for the application of Performance-centered Approach in Mobile Learning for educational and training purposes is to contribute to the continued development of mobile learning and to address the imbalance between mobile devices availability and the lack of education and training provision on the sophisticated communications devices which every student and workers carries and uses constantly – except in education. The advantages for trainees are derived from providing learners with a job aid in their own work context. Given the trend to lifelong learning, many "students" are workers adults with full- or part-time jobs. Mobility offers them an opportunity to maximize their learning time.

Mobile devices are always available and can be used for a variety of learning functionality - providing access to content (both informational and instructional) and for communication and collaboration purposes. They can be used with formal or informal learning purposes as well as performance support, i.e. for delivering information and support just-in-time and in context.

II. Objectives and target population

The IPLECS and mPSS Projects aim: Design, composition and reuse of IPSS_EE LOs and experiment the usage of the learning platform and of IPSS_EE LOs for the physic-engineering integrated curriculum support.

The main purposes of the IPLECS project are:

- Design a master on Information and Communication System (ICS), online, performance centered,
- Apply the ICS master, by means of an educational platform, in Bulgarian Universities involved in the project, Plovdiv University and Technical University of Sofia.
- Evaluate the 'ICS master' in its design, during the process and in their results.

Together with the main objective, others purposes of the project's are:

- Support the development of innovative ICT-based content, services, pedagogies and practice for lifelong learning to support university curriculum in physics-engineering education.
- Provision of open educational resources on-line and testing innovative performance-based e-learning.

The target groups to which the project is addressed are:

- Higher education teachers in physics-engineering and other fields, by transference.
- Students in the same field and, by transference of lessons learned, in other specialities.
- Universities and enterprises management, by transference of outputs and results.

The main purposes of the mPSS project are to contribute to the continued development of mobile learning and to address the imbalance between the availability of mobile devices and the lack of education and training provision on the sophisticated communications devices which every student and workers carries constantly.

The projects objectives are linked directly to support the realization of an European Higher Education Area as much as the development of innovative ICT-based content, and open educational resources on-line provisions, testing innovative performance-based e-learning and contributing to mobile learning development in education.

III. The Project Approach

The project approach responds to the '*Principles of Performance Centred Curriculum'*, which are derived from the first concept of Electronic Performance Support System, but evolved, to adapt it to the Higher Education System.

The Principles of Performance Centred Curriculum: The EPSS concept (Electronic Performance Support System) includes the idea of just-in-time, just-enough, and just-at-the-point-of. This needs computer support for an effective and efficient job performance. An EPSS is an integrated learning environment structured in a particular way to provide immediate access to the full range of information, advice, guidance and tools allowing effective and efficient job performance.

EPSS to PSS in Higher Education is characterized by its focus on active learning, acquisition and application of skills, technology power in addressing instructional issues, appropriate representation and filtering of learning resources and one integrative approach for operational performance support.

The integrative approach to PSS is based in the following learning theories: Cognitive Apprenticeship (Brown, Collins & Duguid, 1996[3]); Cognitive Flexibility theory (Spiro & Jehng, 1990) [4]; Four-Components Instructional Design Model (Van Merriënboer & Kirschner, 2007[2]); Design Theory of Problem Solving (Jonassen, 2004) [8]; Cognitive Load Theory (Sweller, 1994 [5]).

The Performance learning center concept operates by defining a set of authentic problems and constituting tasks related to a specific working environment; shifting the focus from the lower levels of the learning taxonomy such as knowledge and understanding, towards its higher levels such as solving real-world problems; applying adequate summative performance-oriented assessment methods.

The learning support is delivered by the following learning strategies:

- Designing a sequence of easy-to-complex tasks;
- Creating opportunities for deliberate practicing these tasks: giving formative performance feedback;
- Gradually diminishing the amount of support (scaffolding);
- Adapting instructions to students' knowledge level and learning style;
- Providing a variety of instructional stimuli (resources) and
- Allowing constant access to learning resources.

The system is characterized by using recent developments of information and communication technologies (ICT), presenting embedded performance support into the interface and functionality of the application. The system depends on how comprehensively performance and support are defined and how well they are operationalized in the architecture and in the interface of the system.

The Structure of the learning content, for all the courses in the ICS curriculum, lies in:

- Background information (facts, definitions, principles and theoretical frameworks)
- Examples (worked-out examples, modeling examples, demonstrations and simulations)
- Procedures, techniques and tools
- Presenting learning content
- Split-attention principle (People learn better when words, pictures and graphics are physically and temporarily integrated)
- Self-explanation principle (People learn better when they are encouraged to generate self-explanations during their learning)
- Guided discovery principle (People learn better when guidance is incorporated into a discovery-based multimedia environment)
- The main purposes of the IPLECS project are:

'The instructional design for Performance-centered E-learning of DIPSEIL, as a typical performance support system [11], [12], is an integrated electronic environment, which is available via Internet and it is structured to provide individualized online access to the full range of information, guidance, advice, data, images, tools and software to permit the user performing a task with a minimum of support and intervention by others.

IV. The Desing of the Iplecs and MPSS Projects

In the IPLECS Project, the ICS Curriculum Design has been developed having into account 'The Principles of Performance Centred Curriculum' and 'The Instructional Design for Performance-centered E-learning' of DIPSEIL, we have developed 'The Workflow Model for an Information and Communication Systems curriculum'. With these three elements teachers in charge from different courses have enough information for developing the ICS courses.

The Workflow Model also offers to the course developer complete guidelines, with explanations, and examples that give all the partners unified criteria for developing the courses and their activities supporting the ICT performance centered task design.

The IPLECS Workflow Model for curriculum development is based in:

1) State a reference situation in which the students will use what they are going to learn.

2) Formulate a few Learning goals and clear and specific objectives oriented to competences.

3) Create learning tasks with performance support, to provide the students:

  - Background information,
  - Examples,
  - Procedures and
  - Feedback,

  in order to help the students to perform the task easier and also to facilitate their learning.

4) Summative evaluation.

The 'Workflow Model', at the same time that serves as a guideline to courses developer, also works as a complete check-list for evaluation purposes of the ICS courses design, being used as a 'PSS Validity Scale'.

The ICS Master Program and its ***Implementation Plan in DIPSEIL Platform***

The ICS Master Program is integrated by 6 mandatory courses and 4 electives courses. The student should enroll 8 courses in total, divided into two semesters.

- Semester 1
  - Introduction to Information and Telecommunication systems (PU)
  - Realtime and Industrial Communications (UNED-DIEEC)
  - Internet Technology (DEIS)
  - Advanced electronics for information and communication technologies (TUS)
- Semester 2
  - Satellite and Mobile Communications (PU)

- Optical Fiber Communication Systems (CIME)

And two of electives from these four courses:

- Power Supply for TICs Equipment (UNED-DIEEC)
- Multi Media (DEIS)
- Digital Functions Design (CIME)
- Microelectronics and Nanolectronics (TUS)

The different subjects programs that integrate the ICS Master have been developed according to the 'Instructional Design for IPLECS project and the guidelines included in the Workflow Model for IPLECS.

The designers were facilitated to send their reviewed courses to the responsible of PSS Model, in order to check them according to the 'PSS validity scale'. In July - September 2009 the courses designers had sent to the experts in curricula design their courses.

The course started the 15th of October 2009 in two Bulgarian Universities (Plovdiv University and Technical University of Sofia).

The mPSS application is presented as a form of performance support system for educational and training purposes. This is the case of learners who are studding something in relation with their job, studding to improve and promote themselves at work what is really frequent, specially in Distance Universities. The majority of students in Distance Universities choose careers related with their actual job to gain in knowledge and improve their professional practices and to obtain benefices of the relationship with professional-teachers and other students-colleges, in collaborative relations.

The advantages for trainees are derived from providing learners with a job aid in the context of their work:

- Puts training and performance support where their actual work is taking place.
- Allows new skills or knowledge to be immediately applied
- Enables training when it is needed
- Allows use of rich media when appropriate

The advantages for students:

- They have more flexibility and choice in where and when they learn, outside of the wired (or un-wired) classroom.
- Students use the technology in their study that would enhance their readiness for tomorrow's workplace where employers want graduates who know how to use technology for learning and working, as one opportunity/chance for lifelong learning.

Given the trend to lifelong learning, many "students" are working adults with full- or part-time jobs. Mobility offers them an opportunity to maximize learning time [13].

V. Application of IPLECS to MPSS Project

Research by Stoyanov, Kommers, Bastiaens and Martinez-Mediano (2008) [1], shows that the concept of performance support system (PSS) should be implemented adapted to the specific goals and characteristics of higher education. Thus, it is important to keep in mind the specific goals of education when developing the support to improve learning. This means that students should not only be supported to perform the task at hand well, but also to understand underlying processes and concepts. They should learn from performing the task. Furthermore, it is important to keep in mind that when designing mobile PSS, this should be done from the perspective of the learning process and the learner and not from the perspective of mobile technology. [14].

Founding in results obtained in previous research in IPSS in higher education, we propose concrete instructional design steps for four scenarios for the implementation of PSS in mLearning. The scenarios are based on existing learning theories and take into account different learning processes and educational goals. The following scenarios are distinguished:

a) Mobile performance support courseware,

b) Industry-based mobile performance support systems,

c) Mobile social support systems and

d) Integrated mobile performance support learning.

Each scenario requires a different structure and presentation of the content and addresses different educational goals.

VI. The Evaluation Strategies of the IPLECS and the MPSS Projects

Our conception of evaluation is the following: 'Evaluation is the systematic application of scientific methods to assess the design of one program or project, responding to some needs, having into account its goals, action plan, implementation, results and impact, with the purpose of knowing how well works the program to meet goals and achieve valuable results, in order to contribute to its understanding and to guide its improvement, with the criteria of its worth and merit'.

The evaluation strategy of the IPLECS and mPSS projects aims to study the total purposes of the project. Our main objective is to validate the ICS curriculum by means of different strategies and instruments.

To content validity we will use the IPLECS Validity Scale, based in the PSS instructional design.

To check the mPSS-IPLECS characteristic of educational design and the functionality of the platform we will use specific one check-list and usability questionnaires addressed to collect users' evaluation: teachers and students that follow the courses. The evaluation of the 'usability and functionality of the platform' deals with how well the platform satisfies the user needs and requirements. This variable works as estrange variable that should be controlled, because in one online course the way that the platform or the 'system 'works could affect the entire learning process and also the final results.

The instrument to evaluate the platform is a 'usability questionnaire', which is showed in the Annex 1 .Instruments. 'Computer System Usability Questionnaire' based on Lewis, (1995). Beside the questionnaire the platform is evaluate by the peer review technique before starting the courses. The projects partners and teachers, which will collaborate in the Implementation of the ICS curriculum, are the sample to evaluate the platform.

Attitude is a factor that could be an important influence in learning. Only when there is a favourable attitude towards the TICs an e-learner can effectively face web-based learning tasks. Learning requires a positive attitude from the users to show their full potential. [15].

In according with Anastasi [16], attitude is defined in terms of the tendency to react favourably or unfavourably towards a certain class of stimuli, was determined by visible, both verbal and non-verbal, behaviour.

We will use a questionnaire on 'Attitude to learn by computer', based in a Likert scale, valuing every item from 1 to 5, minimal to maximal agreement with the statement contended in every item.

To value the entire learning process we will use specific 'reflective questionnaire' as satisfaction indicators on the learning process. We will collect information by personal interviews to students and teachers, in order to check satisfaction indicators with the functioning of the program, the IPLEC and mPSS models and the dipseil-iplecs platform during the process, taking measurements from teachers and students.

We want to measure the satisfaction with the ICS curriculum, in relation with the ICS curriculum goals, and with the implementation process and their results. These are indicators of impact, in relation with the ICS Master and IPLECS Model.

The research design is the proper of the evaluative research, focused on multiple sources and variables. The methodology is exploratory. We will use descriptive statistical analysis, and value analysis, using quantitative and qualitative data analysis as correspond to the evaluative studies.

The majority of curriculum evaluation models suggest evaluating the planned, enacted and experienced curriculum;

- The planned curriculum is the theoretical curriculum that one intends to implement, that is, the program
- The enacted curriculum is the curriculum that is actually implemented, the program in action
- The experienced curriculum represents the curriculum as it was experienced by its users, such as teachers and students.

Programs, processes and products should be evaluated. This means that we should evaluate not only the match between the objectives of the curriculum and performance outcomes, that means the effectiveness of the curriculum, but also how it is functioning during the execution of the curriculum and how is being used the resources, the IPLECS Model and the media trough the dipseil-iplecs platform.

To summarize, we need to centre the curriculum evaluation in the following:

- Planned, enacted, experienced curriculum
- Process & product
- Objective & subjective variables
- Quantitative and qualitative data
- Teachers' and students' experiences

The data analysis that we will do are:

- Quantitative, descriptive and correlation analysis, by mean of the Statistical SPSS program.
- Qualitative, Grounded theory, Content Analysis, with the 'Quantified Content Analysis, Lexim ancer' program.

The sample from which we are collecting information are the own courses authors, teachers responsible of applying the ICS curriculum, their students, and the partner as experts to validate the ICS curriculum.

VII. Conclussions

Our projects have time duration of two years and nowadays we are in the first years. The theoretical frame-mark and the strategies and resources for its application and evaluation have already fulfilled. In the current year we are applying the course in both project, and following the process to collect information to evaluate their application and results. The evaluation strategy, using quasi-experimental research methods besides qualitative one, give a good expectative to be able to contribute to the scientific community about some advance in both projects, center in PSS in computer and mobile learning device.

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Natural Sciences in the Information Society

First Experiences

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Abstract— **The goal of the GALILEA project is to design and implement innovative programs and curricula, providing solutions to the changed job specifications for engineers and natural scientists and are capable of attracting more female students to these programs. In this article we outline the design, implementation and the first evaluation results of our pilot program, the bachelor course of "Natural Sciences in the Information Society" that started in the winter term of 2007/08.**

Keywords- engineering education; natural sciences education, gender studies; e-education;

I. INTRODUCTION

For years experts have warned that the number of graduates in engineering and natural sciences fails to meet the growing demands in a high-tech society [1, 2] (c.f. Figure 1). Unresolved, this situation will have a strong negative impact on the future development of society and economy. Despite a growing presence of high-tech devices in everyday life, the portion of high-school graduates choosing to study engineering or natural science programs is declining. A negative image of technological studies has been identified as one of the major reasons behind this trend. They are perceived as focusing too much on theoretical issues, while ignoring experimental, hands-on aspects of technological disciplines. At the same time, potential students are alienated by the perceived lack of social relevance and the failure to teach important core skills in school education. In particular, the lack of young women in these fields has been the topic of an intense debate for some time.

When designing gender-balanced courses and curricula, it is necessary to emphasize that technological-oriented programs are not less attractive for women but that women's interests, educational preferences, and requirements differ from those of "standard" male students [3]. In addition, not only women would benefit from such an alteration of curricula also supporting non-technological skills and expertise (e.g. soft skills, analytical competencies, or information literacy). The demands of the economy of the 21st century such as lifelong learning and the effects globalization has on today's employees require engineers and natural scientists to be autonomous, and disciplined. Employees must have sophisticated communication skills such as speaking different languages and working in teams with different cultural backgrounds. In order to accept the challenges, universities have to reconsider their structural and educational concepts.

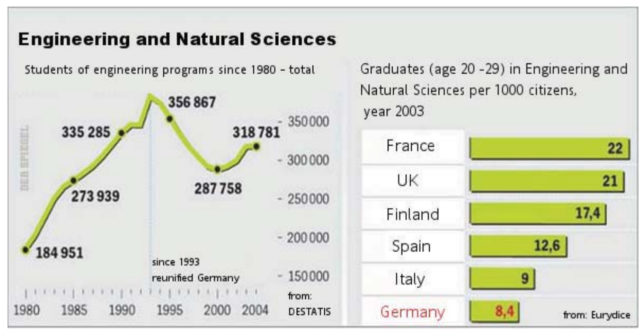

FIGURE 1. Left: Number of students in engineering and natural sciences programs from 1980-2004 in Germany (pre- and post unification), Right: Graduates in engineering and natural sciecnes per 1000 citizens in selected European countries as of 2003. Graph published in Spiegel Online [4], translation added by authors

Due to the Bologna process, European universities have the opportunity to reform their curricula. Within the GALILEA project [5] our goal is to design and implement such innovative curricula, which answer to the changed job specifications of engineers and are capable of attracting more female students. Our first new Bachelor of Science program "Natural Sciences in the Information Society" started in the winter term of 2007/08. If offers a *studium generale* of natural sciences at Technische Universität Berlin (TU Berlin) and can be continued either by a corresponding Master of Science course "Natural Sciences in the Information Society" or Physics, Mathematics, Computer Science or Chemistry.

This article reports on our first experiences, and evaluation results.

II. THE GALILEA PROJECT

Originally, GALILEA was established at the Department of Mathematics and Natural Sciences; however, it is operating as a supporter for many courses at the entire university. The aim of the GALILEA project is to design and implement new gender-sensitive courses within technical and scientific disciplines. Therefore new curricula have to be proposed, combined with modern educational styles overcoming the above described challenges. In this manner, practical aspects as freedom of scope, comprehensive projects, teamwork, and an internship play an important role. The program has been designed with educational preferences of women in mind. It allocates educational key qualifications and interdisciplinary skills as well as leadership and management qualities. Since language requirements have become important, especially in technical and scientific fields, we decided to offer at least some of the courses in English (Figure 2).

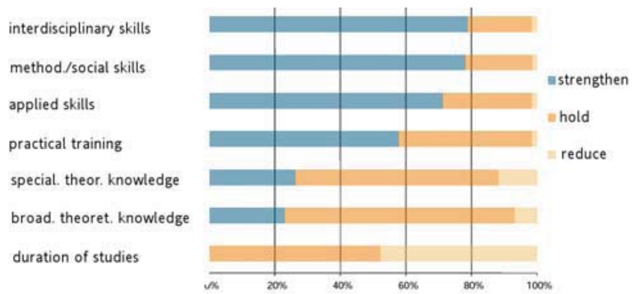

Figure 2. Wishes of the industry regarding programs. Source [6], translation added by the authors

One of the main deficiencies in academic education in Germany is the low attendance of young students in large universities. GALILEA has an integrated mentoring program, especially for freshmen but also for older students.

A. *Natural Sciences in the Information Society*

The “Natural Sciences in the Information Society” (NidI) program as the first GALILEA course started in the winter term of 2007/08 with 15 students (9 female and 6 male) and 37 students (17 female and 20 male) in the winter term of 2008/09. It offers a wide repertory of natural sciences, engineering and non-technological courses at TU Berlin. The core attributes of all natural sciences are the close correlation between theory and experiments and the high standards in mathematical and computer sciences education. These connections are the guidelines of the two-tier program:

1) *Bachelor program*

The NidI Bachelor program provides a great range of access to the basics of natural sciences. The curriculum of this three year program is built on a theoretical basis (59% of the credit points) and supported by a compulsory elective (21%) part, a freely chosen part (10%), an internship (3%) and a bachelor thesis (7%). In fact, students have about 110 compulsory elective subjects to enrich their individual study plan. The technological broadness of the curriculum accommodates the multidisciplinary interests of women. Therefore, emphasis is put on integrating natural and life science aspects. During the concentrated study, the mandatory internship (of at least 12 weeks in duration) has to be concluded. It ought to give an insight into professional life. The theoretical basis of the curriculum is formed by mathematical and physical courses supplemented by several courses in computer science. Additionally, in the first year there are two mandatory modules in scientific information management chosen selected by at least one the following criteria:

- Content-related course of study,
- Teamwork in co-ed teams,
- Teaching core skills,
- Project-oriented work.

Students are taught general scientific methods they will need for managing projects (i.e. experiments), regardless of the explicit fields they will specialize in. Therefore we provide two new project-oriented Bachelor program lectures “Scientific Information Management” and “New Media in Teaching and Research”. The students are taught basics of knowledge management, presentation techniques, multimedia education, and research. The first course is carried out by the staff of the university library, the second by the Center of Multimedia in Education and Research of TU Berlin.

2) *Master program*

After graduating with a bachelor of ‘‘Natural Sciences in the Information Society’’, students have the opportunity to join a master program that will result in the "Master in the Natural Sciences in Information Society". Since the bachelor program offers a wide basis in the natural sciences it is also possible to join other master programs from the natural sciences (i.e. astrophysics or nanotechnology).

3) *Mentoring program*

Students can participate in an internal mentoring program providing organizational, social, and technical aspects. This program aims at improving the educational and organizational atmosphere in large universities by a close mutual relationship between freshmen, older students and academic staff. Our goal is to increase the motivation and performance especially of freshmen and women. Beside individual meetings, we provide a wide offering of social events, and additional non-technological and technological advanced training (i.e. exam stress, programming, or mathematical workshops). The mentoring program also allows us to react quickly if structural or technical problems of the program become apparent.

B. *Aim of the program*

The industry and economy still have a high demand for interdisciplinarily educated graduates with great scientific knowledge (cf. fig. 2). Multi-disciplinary, application and research-oriented programs impart methods and fundamentals of computer science, mathematics and natural sciences. In the bachelor program students acquire the necessary knowledge and familiarize with general and specific methods for treatment and solution of problems in natural sciences. This enables them to transfer their knowledge to practice and create the basis for continuing their academic studies, e.g. in the master program.

The following cross-technical competencies and social skills are mediated beyond the purely technical aspects:

- responsible life-long learning,

- problem-analysis and development of problem solving concepts,
- social, scientific, gender-specific and ethic points of view in action and decision strategies,
- multi-disciplinary communication and ability to work in a team,
- presentation skills including the presentation of scientific results for different target audiences,
- modern methods of scientific information management.

After graduation the students are able to find jobs that require great scientific and methodological knowledge whereas the specific skills are acquired on the job. Some examples are: technology writers and other activities with scientific publishers, scientific librarians, advisory activities in politics/ministries/authorities, project-management in scientific-technical areas, science management at universities and research institutes, activities in financial and insurance companies.

Most of the structure of this multi-disciplinary program is tailored to suit women's preferences, yet the large amount of experimental modules might be a problem. Due to their socialization women frequently underestimate their abilities and do not possess the same degree of experience as men [7]. Experiments and theory are closely connected in natural sciences. Consequently it is neither possible nor desirable to design programs in these areas without experimental components. On the contrary: strict emphasis has to be put on the connection between theory and experiment and on offering additional possibilities for experimenting, e.g. virtual laboratories [8].

The bachelor and master programs "Natural Sciences in the Information Society" are the basis to modernize programs, e.g in physics where in general the ratio of female students is one of the lowest of all programs. The development of a program in astrophysics as the field of physics that is traditionally very attractive for female students could be an example. This is reflected in the numbers of students graduation in physics at TU Berlin: Only about 10% of all physics students are women, yet approximately 30% of all female graduates and scientific assistants choose astrophysics as their specialization.

For a detailed summary of the "Bachelor of Natural Sciences in the Information Society" programs please see [9].

III. Evaluation of the New Courses

Overview

So far students' feedback indicates that we are on the right track. We learned that the high relevance of practical courses and projects in these modules, the extensive access to laboratories and independent experimenting, the possibility of a wide choice and the internship are of special interest for our female students.

The mentoring program of the course also allows evaluating the success of the program itself. This feedback from students is crucial, especially in the first year, in order to make adjustments to the program. This hopefully leads to more support from graduates in the future, e.g. by becoming mentors or providing internships for students.

We evaluated both courses and found out that the concept was generally well accepted. Male students appreciated the courses focusing on gender aspects even more than female ones. The courses were offered a second time, but an evaluation has not been conducted so far To find out if and how the students' point of view changes during the term, each course was evaluated twice. There was a weekly poll for "Scientific Information Management" and a final questionnaire evaluation, whereas "New Media in Teaching and Research" has been assessed monthly and ended with a final questionnaire session. The results will be presented in brief.

A. Integrated Lecture: Scientific Information Management

22 students took part in the weekly evaluation over a total of nine weeks. Every time five male and five female randomly-sampled students were interviewed. The male students followed the lessons a bit more concentrated and took part more actively than female students did. They also expressed to have learned a lot for use in the future.

In the final evaluation, the students evaluated the course with average grades. They expressed that they had learned a lot and were able to transfer it into practice. The students were able to handle the level and scope of this course very well. Different kind of media used in the lessons motivated the students. They preferred to work in mixed teams. The students even appreciated the mandatory attendance of this course because they understood that it was adequate due to the teaching methods applied [9].

B. Integrated Lecture New Media in Teaching and Research

Each of the 20 students (12 male and 8 female) and the three lecturers were interviewed to compare their impressions of the students' participation during the lessons (monthly evaluation). While the assessment of their own contributions to the lessons was balanced around a good average, the lecturers were more pleased than the students thought they would be. However, this changed in the second half of the term.

For the final evaluation, only students were interviewed. They considered this course to be useful for their future and that they would use the learnt methods (e.g. presentation skills) in their everyday life. They really liked this course and graded it with an average of 1.75 on a scale from 1 (best) to 4 (worst). The level and scope of this course were adjusted to the students' previous knowledge. There was no mandatory course attendance, yet 45% of the students visited almost every lesson, 70% attended more than half of all lessons. Four of them would have even preferred a compulsory attendance. The students enjoyed the different kind of examinations ("prüfungsäquivalente Studienleistungen"): There were four different types of exams: an oral exam, several assignments, delivering a scientific paper and a presentation. The students appreciated the oral exam the most (average: 1.42 on a scale from 1 to 4) and the assignments the least (average: 1.95). Referring to these types they claimed to be able to present the topic and their knowledge more easily. Altogether, we found that the concept was well accepted both by male and female students.

Besides the acquired knowledge students developed useful soft skills and applied them immediately in other courses. Although there are some aspects that still need to be improved, the concept seems to be successful. During the present term similar evaluations are carried out to validate these results and to find out what has improved and what else needs to be done.

C. Mentoring

The evaluation of the mentoring program was included all participants – mentors and mentees. All mentors were evaluated through means of a short questionnaire, and all mentees completed four guided interviews with some additional questions included in a short questionnaire. Two female mentees and two male mentees filled out the questionnaires. Respectively, one of each mentees was actively participating in the mentoring program. At the time of the questioning, all mentees were at the end of the second term.

Generally, the acceptance of the mentoring program by active mentees was positive, whereas the temporal effort strongly varied (2 to 9 hours per term). But only one non-active mentee positively reviewed the program. According to the asked mentees the aim of the program is to assist students through a contact person during their studies and especially at the beginning. However, the interviewees seem to have no specific conception of the program. Therefore, the mentoring program was used mostly at the beginning of the studies, in order to clarify organizational questions. If no concrete questions arose, the mentees did not make use of the program. It was criticized that there were difficulties to make appointments and that clear guidelines were missing. Both mentors and mentees should have had a clear conception of the meaning of mentoring. However, if there was a personal relationship between the mentor and the mentee, the conceptions and expectations of the mentees were satisfied. This relationship was characterized as amicable. The general aspects of the mentoring program were of interest to the mentees. This part of the program was also used in parts if the student did not have a mentor.

An obstacle of active participation in the mentoring program is represented by the first appointment with the mentor. If this took place, then generally a good relationship between the two formed. However, different challenges appeared due to the status group of the mentor (student, scientific staff, professor). Thus, appointments with the status group "professor" hardly took place. In contrast, friendly relationships arose out of the status group "students" in which the mentoring becomes less important.

IV. Summary And future Work

Especially the German industry needs more qualified engineers and natural scientists at this point in time. The number of students currently enrolled in the corresponding programs is too small to fill this gap. While more female students could stand in, the majority of these programs are rather unattractive to women. In particular, many students in these fields are not well prepared for their future professional life. Thus, important soft skills or communications skills are needed.

Numerous evaluations [3, 10, 11] prove that the quota of women in the programs mentioned is considerably increased by special adaption to their needs (e.g. multidisciplinary). However, this can only be achieved if the curricula are readjusted. Moreover this can also motivate numerous male students. The awareness in Germany to readjust courses of studies is developing very slowly, yet constantly growing. In addition, there are many efforts to encourage female students. Thus, female students will be supported from kindergarten onward all the way to studies at the university level through scholarship programs. However, the criticism grows that many male students are now facing disadvantages due to the changing gender stereotype settings and activities [12]. Therefore a lot of male school graduates would not continue to university any longer and would also not come into consideration for a qualified profession.

At TU Berlin the mentioned challenges are well-known, and different solutions are being sought out. TU Berlin strives to be a forerunner for new challenges in research, economics, and society, in order to achieve a new image of engineering and natural sciences. One of these approaches is the GALILEA project financed by the European Social Fund (ESF). GALILEA is designing programs in order to increase the quota of women in engineering and natural sciences by integrating specific female requirements and new educational paradigms. Through the Bologna declaration [13, 14] the incentives for completely new programs are provided since the two-tier bachelor and master system is a completely new structure in the academic education in Germany. Therefore, the GALILEA project designed the new program "Natural Sciences in the Information Society" aiming at a quota of about 50% female students. This new approach is integrated not only into the concept of the entire program but also through the individual lectures "Scientific Information Management" and "New Media in Teaching and Research".

These two lectures for the Bachelor program were evaluated. Generally, the lectures were positively assessed. During the first run of these lectures students identified some technical procedures such as high expenditure of work or too many examined topics to be disadvantageous. The multidisciplinary approach was assessed as good, and the students had the feeling that the lectures impart soft skills that can be useful in further studies or future jobs.

In addition to the changed curriculum a mentoring program is integrated into the GALILEA program, accompanying students throughout their studies. An evaluation of the mentoring program took place as well. Here, the biggest issue found was that the meaning of the notion "mentoring" is not universally understood, in spite of efforts of explanations in training courses. Students are already aware of the existence of a contact person, but this offer is accepted mainly in the first term. Nevertheless, the program was evaluated positively. A good approach was to enlist sophomore students as mentors for their freshmen fellow students. The developing relationships are considered amicable and lasting.

In further evaluations, we would like to examine specific problems within the lectures and the mentoring program to improve our courses.

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Session 04G Area 5: Gender Issues in Engineering Education

Real Projects to involve undergraduate students in CS degrees
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Who enrolls in electrical engineering? A quantitative analysis of U.S.A. student trajectories

Camacho, Michelle Madsen; Layton, Richard A.; Lord, Susan M.; Ohland, Mathew W.

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Achieving and Sustaining Gender Balance in an Undergraduate Teaching Institution

Eppes, Tom A.; Milanovic, Ivana; Sanborn, Jennifer
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SPIRIT - A Life-Cycle Based Gender Mainstreaming Concept at the University of Stuttgart

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Real Projects to involve undergraduate students in CS degrees

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Abstract— **Technological advances are improving the standard of living and working conditions. Curiously, the number of students that choose technological studies and careers continues to decline. This fall is particularly noteworthy in respect of females.**

One of the main reasons for this is that neither the model of professional profile promoted, nor the global approach of the mission is attractive or appealing.

Some studies indicate that problem-based and project-based learning methods are conducive not only to acquiring social and interpersonal skills that are valuable in a workplace, but also to increasing gender diversity in engineering degrees [9].

In this paper we present a pilot project, ICT4Girls. The main goal is to diffuse computer science as a real tool for service of society, with a principal aim of promoting ICT careers.

Based on a wireless sensor network (WSN) platform, several real projects by undergraduate students are presented. For our purposes here, two projects have been defined. Beginning from a basic-skill framework, each presents a different audience and goals.

Computer Science, technical skills, Profession, Real-world Project

I. Introduction

The lack of technological vocations is a reality in undergraduate studies as well as in professional careers [1]. This is particularly noteworthy in respect of females

One of the main reasons for this points to the lack of knowledge of the professional profile in the computer science field [2]. Teenagers and undergraduates do not have clear models in their lives (neither real people nor fictional characters). Consequently they do not know the kind of job an IT professional performs, and do not pursue the corresponding degrees (Computer Science and Computing Engineering) as an option relevant to their future career.

One possible solution to this problem may be to introduce a real project in the curriculum: describing a problem, devising a specific solution and making the implementation in a real platform.

Choosing a people-centric project to improve their own community (school, neighbourhood, shopping-mall) they will become familiar with the social aspects of their future job. This aspect is a fundamental part of making Computer Science appealing to new generations: to appreciate the tangible improvements that transpire from their own technical work for both the environment and the people.

These project-based classes also have the advantage of allowing the student to develop other professional skills such as leadership, teamwork and decision making analysis.

Similarly, they offer scope to learn and improve technical skills such as modular and parallel programming, event management or testing experiment design, as well as new areas of interest including open source software, low power analysis and mobility.

With this in mind we present a foundation to develop real projects based on a wireless sensor network (WSN) platform and two project proposals presented by undergraduate students [3].

The rest of the document is organised in the following way: in the next section, we describe the project goals and introduce our project-based proposal. In the third section, we introduce the basic platform to develop our framework. In section four we present our methodology and two current projects, each with different characteristics and requirements. Section five presents some related work in the project-based learning methodology field. Finally, section six deals with the conclusions and future work.

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II. OUR PROJECT-BASED LEARNING APPROACH

There are well-known references and experiences [9][12] which show project-based learning to be a methodology that connects better with the skills required by employers and encourages the recruitment of more women engineering students [9]. The research in the area shows that learning is a rich context of experiences, not only based on abstract information, but on the exchange of this through hands-on experiments, social activities, community discussions, and real problem solving, among other forums.

The main concerns when designing these types of courses are 1) how to link them with other previous courses; 2) how to use the course to learn specific social and other transferable skills and 3) how to acquire the desired technical and science skills.

The choice of the platform and environment used to build the project is as important as determining the objectives and methodology to accomplish all of these three goals. This platform should allow for a variety of situations to promote creativity, acquire professional habits and attitudes, and to improve their comprehension in computing, among other goals.

Another important point for this choice was that secondary students already had familiarity with these devices (sensors, network issues, etc), so they were able to share experiences and even participate in the projects with undergraduate students.

In this project, we have chosen a wireless sensor network platform and the activities have been designed jointly with a technological enterprise DEXMA, http:www.dexmatech.com, which provides professional expertise and advice on the appropriate devices. They are also in charge of introductory seminars.

To initiate the activity, we engaged a reduced team of female students to participate in a program to introduce secondary female students to ICT careers. In this program there were two main activities:

- To present a set of solutions to current problems using well-known technology and devices;
- To introduce personal experiences of undergraduate life on Campus.

From these activities, we had the beginnings of the first project, in which both undergraduates and secondary students participated (see 4.1).

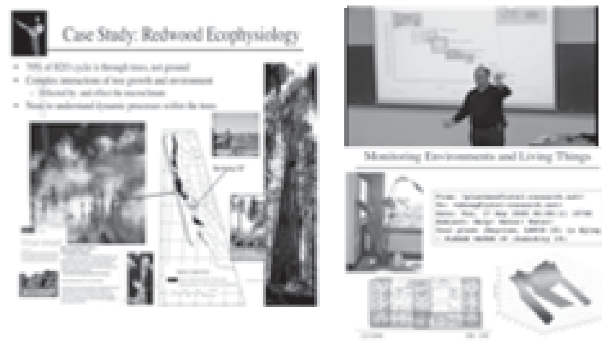

Fig. 1. Introducing technology and familiar devices to manage real current problems.

A. Link with previous courses

A main goal in project-based learning (PBL) is to improve usability, deeper element knowledge and a more mature relationship between different subjects, already done.

In our case, the sensors are programmed in a specific C-like language –nesC- based on events, the servers that receive data are programmed in C++ or Java, and user applications can be programmed in more user-friendly web or graphic-based languages. In addition, scripts that act as glue for the different parts of a complete application should be written in python.

Programming language requisites are covered in lower-level courses for students of Computer Science, as well as Computer Architecture and Network Systems introductory courses.

Some other courses such as graph theory, statistics and other mathematical topics are also interesting and can improve the project results.

Obviously, depending on students' background, the project definition and goals must be adapted.

B. Social habits and attitudes

The European Parliament and the Council of the European Union defines key competences as "…those which all individuals need for personal fulfillment and development, active citizenship, social inclusion and employment. By the end of initial education and training young people should have developed the key competences to a level that equips them for adult life, and they should be further developed, maintained and updated as part of lifelong learning" [8]. And it sets out 8 key competences:

- Communication in the mother tongue;
- Communication in a foreign language;
- Mathematical competence and basic competences in science and technology
- Digital competence;
- Learning to learn;
- Interpersonal, intercultural and social competences and civic competence;
- Entrepreneurship; and

- Cultural expression.

The last three competences are qualitative, personal and subjective skills more related with personal attitudes such as willingness to listen to, to look at, to discover the needs of the other. Being capable of interacting with the resources, using the technology to make a more comfortable, more sustainable world, and to facilitate and to improve the quality of life of people, offering specific services – these are all skills which will be addressed in different ways by the projects we propose.

Engineering education should promote "habits of mind" [1] aligned with what many believe are essential skills for citizens in the 21st century. These include systematic thinking, creativity, optimism, collaboration, communication and attention to ethical considerations [10]

In engineering areas employers seek "people persons"- people who not only have technical knowledge and technical skills, but those who also have interest in the human needs and environmental issues [9].

"The engineer of 2020: visions of engineering in the new century ", [11], takes these aspirations a step further in chapter 4 by setting forth the attributes that will be needed by the graduates of 2020. These include strong analytical skills, creativity, ingenuity, professionalism, and leadership.

The environment where the projects are carried out is the Campus of UPC with the university community acting as "the society". The applications chosen to work on come from the community's needs and research work on the community's style of life. In this way, students also have to learn to communicate with the user (listen to and understand the real needs, establish feedback channels to make progress, decide the best user-application interface, etc.).

Specific examples of the social and communication skills (potentially) included in each project will be considered in a separated paragraph when explaining the respective project. Again, depending on the skills targeted, the basic model of a project can be modified to suit.

C. Technical skills

PBL courses assume that main technical skills are already acquired [7] in the previous courses, as see in section 2.1. With their technical skills, students have to manage the different programming models and network connection programmability; decide the communication model to use (master-slave, pervasive, mesh connection); propose the data structures to keep information; design the user-interfaces to input/output information, etc.

However, some specific tools should be provided to help participants apply their (often rather generic) skills to a real situation with very specific demands. In our referenced projects, these tools include the following two examples. First, a weekly seminar to introduce students to how-to-do issues: system configuration and setup, application examples, etc. Two of these seminars were organized by DEXMA. Second, a twice-monthly team brainstorming session to share the experiences and work done by each team member and to propose new applications and services to develop.

[1] The committee has adopted the term "habits of mind", as used by the American Association for the Advancement of Science in Science for All Americans (1990) to refer to the values, attitudes, and thinking skills associated with engineering.

III. A WSN FRAMEWORK FOR USE IN PROJECTS

The technological basis for the project is a pervasive and ubiquitous platform with wireless sensor networks (WSN) to collect data. This data should allow for the development of different applications to improve the site and to make it more user-friendly.

Our first location is a University Campus (Campus Nord in UPC). The sensors capture temperature, luminity and presence to be processed in different ways by the various proposed applications. There will be some servers distributed throughout the Campus to collect and manage data. End users will connect via wireless to different applications depending on the information needed. Data connexion will be through the Campus wireless service, via intranet. In this way we can guarantee security and privacy in accessing the data.

Different sensor distribution in the area can restrict the different configurations to collect data. So, depending on whether there is a master reading all of the information or the information is based on a "multi-hop" style, some decisions have to be taken about network connections.

This general framework, with minor modifications, can be adapted to different contexts; for example a shopping mall, a school or a neighbourhood.

Once the infrastructure to work on is decided, we have to consider other aspects:

1. How to introduce students to programming WSN. A weekly seminar.
2. How to express the "social skills" as demanded by the European Parliament (last three on the list above).
3. Which applications are most suitable to develop. To do this students have their own meetings, brainstorming with other classmates, and sharing information from related projects and papers.

Starting from the basic platform, the applications will be proposed by the students, following one of two main models:

A. Energy-saving oriented: in this case, the information given is more general, related to resource use such as lighting or heating. It can be used to promote sustainability and power management in everyday personal and working activities.

B. Service oriented: the information provided is used to give specific services the users require on demand.

In the next section we explain the general methodology we follow in the projects and we present a representative example for each one of the application models: a monitoring application and a parking alarm.

IV. Project based learning methodology

PBL is based on contextualized content. Usually the teacher works with a case that would have been real originally but it has no real-world immediacy for the students, and they consequently fail to engage with it. Additionally, these relatively abstract problems may or may not eventually arise in the real world. This can also dampen students' enthusiasm for fully applying themselves to the task.

For us it is very important the student detects the problem and looks for a solution: the student's role is active and allows for the developing of two basic competences in the entrepreneurial world. The first is to translate the user needs into technical words; the second, to work with different disciplines if necessary.

A. Firs project: Maximizing energy efficiency

This is a real project lead by students in collaboration with a technological enterprise, DEXMA [4]. The goal of this project is to sensitize people to energy saving by improving their habits in lighting and heating.

With this project we want to acquire not only technical skills, but also skills like the concern for human needs and environmental issues.

From the initial WSN platform deployed throughout the Campus, we monitor the temperature at different points to be able to quantify the energy we waste. This data collected will be the basis for an application – called AmbientReader- that allows us to measure the energy wastage and then propose different solutions [5].

For example, we measure the temperature in a classroom. A temperature higher than 21ºC when the room is full means that the place is overheated, so energy is wasted.

Steps to follow:

1. Characterization of the place to study. The study is done in the classroom buildings (see Fig. 1). First, we need to determine the temperature characteristics to take into account, For example, whether or not there are variations depending on the floor level, the orientation (north, south, east, and west), the time of the day, or the amount of people inside the room. The goals in this step are:

- To choose the most suitable position to place the WSN (ends of Campus, ends of each building, different floors);
- To measure the temperature changes depending on the classroom being in use or not (full or empty rooms);
- To measure how the temperature changes based on the time of the day (morning, noon, evening).

2. Evaluation of the fine tuning. The turning-on and turning-off of the heating needs time and has an associated delay which we can estimate as a constant value, so we will determine if it makes sense to stop or reduce the heating and for how much time do so. The goals in this step are:

- To calculate the time and temperature at which to turn on heating;
- To combine the two influences on temperature, the ambient and the dedicated, to maintain the temperature within the range of comfort.

This project is a practical example of technology being socially relevant [6].

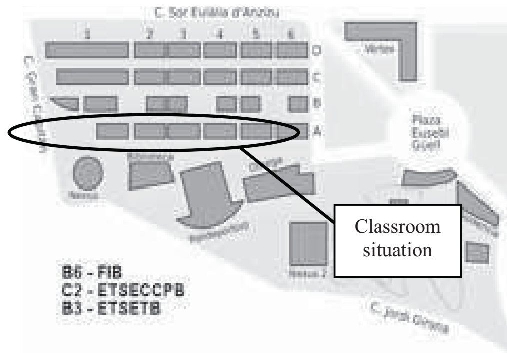

Fig. 2. Campus Nord map remarking the classroom situation, at South

B. Second project: Friendly parking

The second project also contributes to a friendly environment in that it helps to decrease CO2 emissions, but the main focus is more clearly customer-centred. The aim to facilitate parking is a real client need.

In this case, the proposal was born on the initiative of a participant to improve Campus services after having heard some user comments.

Campus Nord has a parking facility for the University community with 190 locations. The car park works as follows:

There is a single-direction traffic flow, so cars enter by one street (Sor Eulalia d'Anzizu) and exit by the opposite (Gran Capità).

If a car can't find a place, other cars might have their exit impeded; also there is a lot of waste in time and gas while looking for a parking.

Fig 3. Campus Nord map remarking the parking part, at North

The goal of this project is monitoring car parking to inform users when a place becomes free and where this free place is. When a space becomes free, the application will send a notification, via e-mail or sms. In addition it is possible to visualize the map with the exact places free in real time

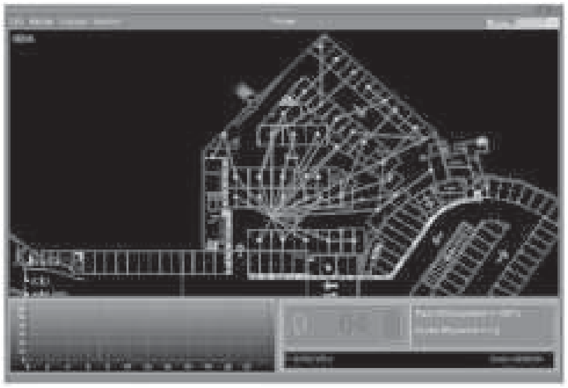

Fig. 4. An exemple of a mesh connection map

Again, the technical basis is a WSN with a sensor in each of the car spaces. The electronic device (mote) works with batteries, is able to detect the presence of a car and broadcast the information up to 70 m. to other devices. All devices form a mesh monitoring all the places in real time and communicate with the server, which manages information and offers a set of services to the users.

When a driver arrives to the Campus, if there is no parking he/her will notify the fact to the server (via mail, sms or web). The server has a specific policy to schedule demands, as it might be chaotic if all clients received a free-place notification at the same time.

A position map can be consulted from home or from the mobile phone, so it is possible to select different ways to reach the Campus. A warning system can be added.

This example has different levels of work, and students might be oriented just to one or combine several, in different teams, or courses, even course-level, depending on their background. For example, there is a very interesting study on the user-side: how to present the information, in which interface, how to warn (e-mail, sms, etc),... On the other hand, the technical concerns are also, very appealing and can be managed in different ways of expertise: how to detect a free place (automatically when the car goes or the car proprietary sends a message, etc), and so on.

V. RELATED WORK

There is a 2007 work from University of Waikato (New Zeland) [12]. In contrast to our proposal, the guidelines of the Waikato project are more rigid, the ends are more abstract, having no final application in the University community, and consequently this may appeal less to females.

Other PBL works are based on playing a role like the EnROLE project [13]. In this case, students and teachers play a role representing users, clients, businesspeople, etc. Again, in our proposal these roles are real and not imagined. The authenticity of the roles in our scheme makes the experience more "immediate" for the participant, and provides a more stimulating and rewarding learning environment.

Maybe the most comparable work is the Open Ended Project [7]. We differ from OEGP in the framework and how it will be established to set up the project, and also in the problem definition itself. Our priority is to produce a practical solution to a real-world problem, defining this solution through close communication with the "end-user".

Additionally, in this paper we present types of project that are suitable due to the skills they provide to students, while the OEGP approach looks for a specific course, with objectives, requirements, and so on.

VI. CONCLUSIONS AND FUTURE WORK

In this paper, we introduce two real projects to be used in PBL classes. This methodology "with more contextualised content resulted in an increased recruitment of women along with a substantial level of appreciation of learning" [9].

Reflecting on social contributions by their own profession improves students disposition toward technical careers. Additionally, the enthusiasm to contribute to their own community fuels the development of accomplished professionals.

On the side of the community, an increased awareness of the contribution of engineers and IT specialists leads to a more positive vision and higher valuation of these professions.

These two positive streams help create a virtuous circle.

Additionally, the technical platform for the projects (WSN) aims to introduce courses related with these subjects to allow students to acquire competence in these new future areas. Development solutions for the future involve the integration of mobiles with other IT as a usual scenario.

As explained above, our pilot projects have been developed as collaboration between undergraduates and high school students. The main goal was to engage females in ICT degrees, by becoming more familiar with the kind of work that is being developed in these areas. Although this is an ongoing experience, we have already received positive comments and reactions:

1. We have a positive influence on people's vision and behaviour regarding to technology, promoting personal and professional attitudes. For example:

- Fostering interdisciplinary dialog channels between people –students, teachers, and professionals-.
- Incentivize research into low-power high-tech (specialized processors, optimized code, power measurement tools, etc.).

2. We have collaborated with secondary school research projects:

- A team is implementing a similar project using a simpler, well-known technology in their own school;

- A student is using the same platform to monitor her home with its different climatization conditions (air conditioning, fan or blinds).

The approach we present will be also used as WSN hands-on material in laboratory courses, or along the degree in several courses.

Other future students' proposed applications are:

- To confirm whether or not a room is in use.
- To know in which of the bars on Campus there is a free table.
- To know if there is a free table in the Campus library.

In a more advanced phase, we plan to include also the participation of Electronic Engineering students to develop new hardware and sensors, as well as collaborate with other degrees to work in multidisciplinary teams.

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Who enrolls in electrical engineering? A quantitative analysis of U.S.A. student trajectories

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Abstract **Electrical Engineering (EE) is one of the largest engineering disciplines. Analysis of the student population specifically within EE provides insights into a large segment of the undergraduate engineering population. Using a dataset from universities in the United States of America that includes over 70,000 students who majored in engineering, this work considers the subset of that population matriculating in EE. The rates of EE matriculation and six-year graduation vary by race and gender. The relevant findings are that males out number females at all levels of undergraduate EE. EE is the most popular choice for Asian and Black males at matriculation and the second choice (after ME) for Hispanic and White males. EE is much more popular for Asian and Black females than Hispanic and White females at matriculation and graduation. In fact, more Black females graduate in EE than in any other engineering discipline. The six-year graduation rate of EE matriculants is higher than that of students of other engineering disciplines. These findings suggest the importance disaggregating by engineering sub-discipline and examining how such information is useful in improving recruitment and retention overall.**
Keywords-Electrical Engineering, retention, race, gender

I. Introduction

There have been numerous calls to diversify the engineering profession [1, 2]. Electrical Engineering (EE) is one of the oldest engineering disciplines dating back to the 1880s [3] and also one of the largest. Thus analysis of the student population within EE provides insights into a significant segment of the undergraduate engineering population. Despite having high enrollments of students, EE has one of the lowest percentages of women students around the world including in the U.S.A. [4], Canada [5], and Israel [6].

Many studies of undergraduate student persistence aggregate all engineering disciplines [7, 8, 9, 10, 11]. This may often be a practical limitation imposed by the available data that results in small datasets when disaggregated by engineering discipline. For example, York Young and Redlinger [12] analyzed the student flow for 23 EE matriculants at one institution over six years. They found that 14 (61%) of the EE matriculants graduated in six years. Six of these were in EE, three in Computer Science, and one each in five other majors. Humphreys and Freeland [13] found that 68% of 422 EECS matriculants at one institution were still in the major after four years. They note that women were a small fraction of the cohort and persisted in engineering at lower rates than men and switched out of the major at higher rates than males.

Given our extensive dataset, we are able to disaggregate not only by engineering discipline but also by race and gender. This permits an investigation of EE students at an unprecedented scale and detail. In this paper, we examine how the matriculation and six-year graduation patterns of EE matriculants in the U.S.A. vary by both race and gender.

Research on retention of women in science, technology, engineering, and mathematics (STEM) disciplines in general and engineering in particular contains "conflicting evidence" regarding gender differences in persistence [14, p. 23]. A variety of studies have reported that women matriculating in engineering majors persist at the same rates as men [8, 9, 14, 15, 16, 17, 18, 19]. Other studies found lower persistence for women in engineering [7, 10] although these contained unique metrics for success which are difficult to compare with others.

Despite the sparse evidence supporting the claim that there is a gender gap in engineering persistence, there is a pervasive popular belief that women persist at lower rates than men. One source of this assumption is the inclusion of studies that measure persistence from pre-college STEM intention rather than college matriculation. Starting at this earlier point reduces the overall persistence rate and conflates the gender gap in pre-college choices regarding college STEM enrollment with the persistence after matriculation. Another likely reason for the belief in a gender gap in persistence is the severe gender gap in the enrollment-presence of women, which may be confused with the persistence of women. Overall, a careful investigation reveals that amidst some conflicting evidence, most research finds no significant difference in men's and women's engineering persistence rates. The gender gap in engineering is not a problem of persistence; rather, it is the result of fewer women enrolling in engineering compared with other majors.

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In analyses of engineering persistence, it is important to adopt a critical race theory framework [20] and consider the intersectionality of race and gender. Intersectionality refers to how gender operates together with race, not independently, to produce multiple, overlapping forms of discrimination and social inequality [21]. Failing to disaggregate data on women by race produces results that are over-generalized rendering minority women “invisible”. Women in engineering do not necessarily share common experiences of marginality. For example, women of color may experience both sexism and racism, compounding their experiences of exclusion.

Reichert and Absher [22] reported data on minority retention rates from the National Action Council for Minorities in Engineering (NACME), but they neither tracked individual students nor disaggregated by race or gender. May and Chubin’s significant 2003 study for NACME [23] spoke clearly to the issue of representation of underrepresented minorities disaggregated by race and gender, but did not disaggregate by engineering major and did not track individual students to address the issue of persistence or graduation rate. Cook and Córdova [24] also disaggregated by race in their study of representation. Each of these studies provided valuable data relating the importance of examining race within engineering. Yet, understandably, each study was limited in scope because of the difficulty involved in examining all relevant variables: race, gender, cohort, major, matriculation status and persistence to graduation.

The vast majority of undergraduate engineering degrees in the U.S.A. are awarded to students who identify as “White”[1]. In 2004, Whites received 65% of the engineering bachelor’s degrees. Asians received about 12% of engineering bachelor degrees). Hispanics received about 7% of these degrees. Blacks received 5% of all engineering degrees while Native Americans account for less than 1% [25]. Except for Asians, each group received about the same proportion of non-engineering STEM degrees. In 2005 [26] about 1/3 of the bachelor’s degrees for Whites, Blacks, Hispanics, and Native Americans were in science and engineering fields. By contrast, almost half of the Asian graduates earned bachelor’s degrees in science and engineering. There is a wealth of literature on the experiences of people of color within science and engineering, yet much of this research aggregates science, math and engineering (SME) and/or underrepresented minorities: Blacks, Hispanics, and Native Americans and does not disaggregate race and gender.

A comprehensive study [27] found that Black and White students are as likely to select STEM fields of study and to persist for three years, but that differences accrued to graduation—62.5% of Blacks persisting for three years graduate within six years compared with 94.8% for Asian Americans and 86.7% for Whites. Yet these persistence issues may not be related to majoring in STEM disciplines alone. Rather, low minority persistence in STEM is a microcosm of low persistence in higher education. Research by Elliott et al. [28] found that ethnicity was not a predictor of persistence beyond what could be explained by ability as measured by scholastic aptitude tests (SAT) math (SATM) scores and achievement (high school grades). The SATM scores of Blacks and Hispanics are known to be substantially lower (1 and 0.75 standard deviations respectively) than those of Whites [29]. Large differences in persistence result when comparing high-performing Blacks’ (62% persistence per Hilton et al., 1989) to a broader cross-section of Black students (34% persistence per Ref 28).

Asian students are unique among students of color in engineering because they are not underrepresented, and they demonstrate the highest persistence [13, 30, 31]. They show the strongest predilection for engineering and the smallest proportionate losses in SME majors during their undergraduate years [7]. Smyth and McArdle [32] reported a 63% graduation rate for Asians matriculating in SME, as compared to 55% for Whites and 38% for underrepresented minorities including Black, American Indian, and Hispanic students (p.371). Similarly, research by Bonous-Hammarth [33] indicated that Whites and Asians had similar attritions rates from SME majors (25% and 26%, respectively) considerably less than the 44% for African American, Hispanics and Native Americans.

The Hispanic population is the U.S.A.’s fastest-growing minority group [34]. Demographic predictions suggest Hispanics may be poised to have the greatest effect on engineering education [35]. Yet the educational gap between Hispanics and other groups continues to widen, especially in engineering [36], possibly as a result of factors affecting Hispanics’ participation in education generally, such as health care, nutrition, adequacy and stability of housing, neighborhood environments, and a lack of engineering role models [37, 38]. Similar to women and Blacks, among Hispanics the proportion of bachelor degrees awarded in engineering has only marginally increased since 1991 [39]. Nonetheless, there is room for the numbers of Hispanics to increase in engineering because this major is the third most popular destination (after social sciences and psychology) among Hispanic bachelor degree recipients.

Native American women are much more likely to participate in higher education and to earn bachelor’s degrees than Native American men. Yet, like all women, they are less likely to choose science and engineering fields as college majors [40, 41]. In 2004, Native American women accounted for only 0.5% of engineering students in the U.S. A. [25]. From 1995 to 2005, Native Americans remained steady at approximately 0.65% of all undergraduate engineering students [42]. Of those Native American students receiving bachelor’s degrees, approximately 4% were in engineering [26]. Besides Lord et al. [16], no other references with details on the persistence of Native Americans in engineering could be found.

[1] In the U.S.A., the racial category “White” refers to people of European, Middle Eastern, and North African descent “Asian” refers to people with origins in any subcontinents of the Far East, Southeast Asian, or India. “Hispanic” refers to those who trace their origin or descent to Mexico, Puerto Rico, Cuba, Spanish speaking Central and South America countries, and other Spanish cultures. “Black” refers to Americans of African descent. “Native American” include American Indians and Alaska Natives. More details are available at http://www.census.gov/

II. METHODS

This study uses the Multiple-Institution Database for Investigating Engineering Longitudinal Development [11, 43], a dataset with more than 79,000 students matriculating in engineering at nine southeastern institutions that awarded 1/12 of all U.S. engineering bachelor's degrees from 1987 to 2004. The results should be generalizable to large public institutions. We focus on first-time-in-college U.S.A. citizens / permanent residents matriculating directly in an engineering discipline including Electrical (EE), Mechanical (ME), Chemical (ChE), Civil (CE), and Industrial (IE). Due to the small numbers, Computer, Materials, and other engineering fields including Bioengineering are not considered. In the population studied, the number of students in Bioengineering is two orders of magnitude smaller than the largest majors preventing disaggregation by race and gender. Students self-report gender and race choosing among Asian, Black, Hispanic, Native American, and White (as well as Non-Resident Alien and Other, each of which are not included in this study). Since we have whole population data, inference is unnecessary—all reported differences are valid. Note that students who matriculated into "first-year engineering" are not included here, since we are studying the disciplinary character of matriculation. Graduation is defined as having graduated by the sixth year following a standard of reporting by the Integrated Postsecondary Education Data System (IPEDS) [44]. Thus, in this paper, we consider students who matriculated from 1988-1998 and graduated six years later.

III. RESULTS

A. *Context and Rationale for Studying EE*

To contextualize our results for EE students, we begin by showing the numbers of students enrolled in various engineering disciplines at semesters 1 and 12. Women and men prefer different engineering disciplines at matriculation and graduation [45]. Table 1 shows the number of women and men at matriculation (Sem 1) and six-year graduation (Sem 12) for Asian, Black, Hispanic and White students. The top two choices of men at matriculation and graduation are Mechanical (ME) and Electrical (EE), yet the order varies by race. At matriculation and graduation, Asians and Blacks prefer EE to ME while Hispanics and Whites prefer ME to EE.

For women of all races, Chemical is the top choice at matriculation. EE is the second choice at matriculation for Asian and Black women while ME is the second choice for Hispanic and White women. Similar to the men, at matriculation and graduation, Asian and Black women prefer EE to ME while Hispanic and White women prefer ME to EE. By graduation, IE is the most popular major for Hispanic and White women, Asian women still prefer Chemical, and Black women prefer EE. The large number of students matriculating in EE results in a large number of students of all race-gender combinations in that population, making it suitable and interesting for detailed study. We next consider those EE matriculants in more detail disaggregating by race and gender.

TABLE 1
NUMBERS OF STUDENTS MATRICULATING IN (SEM 1) AND GRADUATING IN (SEM 12) ENGINEERING DISCIPLINES BY RACE AND SEX.

	Women at Matriculation (Sem 1)				Women at Sem 12			
Major	**Asian**	**Black**	**Hispanic**	**White**	**Asian**	**Black**	**Hispanic**	**White**
Chemical	147	711	48	1110	91	330	19	448
Civil	45	370	42	699	21	179	22	412
Computer	68	183	18	224	34	31	2	71
Electrical	107	701	33	502	79	339	14	242
Engineering, Other	37	72	24	428	13	34	8	158
Industrial & Systems	51	365	40	480	56	316	37	527
Materials	11	32	6	244	6	29	8	161
Mechanical	75	402	44	1048	35	237	18	444

	Men at Matriculation (Sem 1)				Men at Sem 12			
Major	**Asian**	**Black**	**Hispanic**	**White**	**Asian**	**Black**	**Hispanic**	**White**
Chemical	282	432	77	2355	146	173	35	1042
Civil	131	645	132	2931	65	250	70	1759
Computer	373	302	133	2174	219	74	64	1041
Electrical	674	1695	248	4646	453	714	121	2331
Engineering, Other	68	77	40	1044	27	26	19	418
Industrial & Systems	96	350	116	993	120	231	113	1160
Materials	58	44	28	633	35	31	22	478
Mechanical	522	1220	329	7053	279	530	130	3275

B. Matriculation in EE

Table 2 shows the number of EE matriculants and their percentage among engineering matriculants disaggregated by race and gender. The top panel of Figure 1 emphasizes that men of each racial group are more likely than women to matriculate in EE. A similar gender gap is found for ME and Computer Engineering but not other engineering disciplines studied [45]. Overall, 12% of women and 19% of men choose EE at matriculation. Of all racial groups, Black students choose EE at matriculation at the highest percentages of all subpopulations. Of Black men who matriculate in engineering, 30% choose EE, the highest of any group. The second highest percentage is 24% for Asian males. EE attracts 21% of Black women in engineering, the highest of any group of women with the second highest percentage being 14% of Asian women. Notably, only 8% of White women matriculate in EE resulting in a smaller number of White women than Black women despite the greater presence of White women in Engineering.

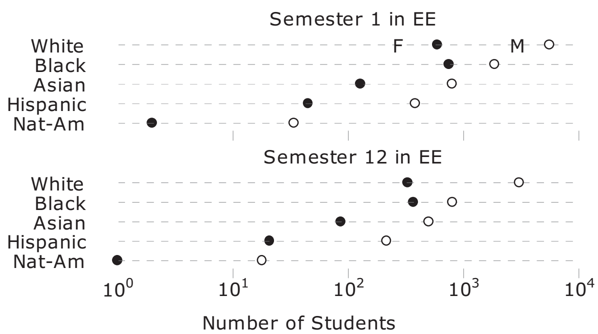

Figure 1. For all races, more men (open circles) than women (filled circles) matriculate and graduate in EE.

C. Six-year Graduation

The bottom panel of Figure 1 emphasizes that more men of each race also graduate within six years in EE than women [45]. Table 3 shows the number and percentage of EE matriculants who graduate in six-years in EE, percentage who switch from EE to another engineering major, and percentage who graduate in any engineering major. As shown in Figure 2 (for populations greater than 30 to avoid computing percentages of small numbers) the percentage of EE matriculants who graduate within six years in EE varies by race and gender from a low of 30% for Hispanic women to a high of 57% for Asian women. Asian students do particularly well in EE as evidenced by their high EE graduation rates. Asian and Black women EE matriculants graduate in six years in EE and engineering (ENGR) at a rate equal to or higher than men of the same ethnic group. Black women graduate at 43% compared to 38% for Black men. White men and women EE matriculants have very similar graduation rates: 41% of White men and 40% of White women EE matriculants graduate in EE. 56% of White women graduate in some engineering discipline compared to 55% of the White men. Except for Hispanic women, the graduation rates of female EE matriculants is consistent with other reports of performance of engineering matriculants disaggregated by race [16].

TABLE 2
NUMBERS OF STUDENTS MATRICULATING IN EE AND ENGINEERING BY RACE AND SEX. DATA ORDERED BY % CHOOSING EE.

Race & Sex	No. in EE	No. in ENGR	Percent EE
Black Male	1695	5707	**30%**
Asian Male	674	2799	**24%**
Black Female	701	3365	**21%**
Native-Am. Male	26	136	**19%**
Hispanic Male	248	1416	**18%**
White Male	4646	29286	**16%**
Asian Female	107	757	**14%**
Hispanic Female	33	332	**10%**
White Female	502	6673	**8%**
Native-Am. Female	2	39	**5%**
All Female	1345	11166	12%
All Male	7289	39344	19%
ALL	8634	50510	17%

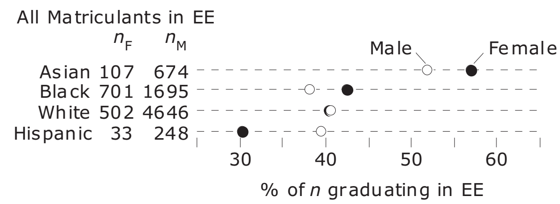

Figure 2. Except for Hispanics, more women (filled circles) matriculating in EE graduate in EE within six years compared to men (open circles).

If EE matriculants graduate in an engineering discipline, they are most likely to graduate in EE of any engineering major for all races and genders. By six years from matriculation, fewer than 16% of EE matriculants switch from EE to another engineering major. Within that 16%, women and men of each ethnic group are equally likely (within 2%) to switch from EE to another engineering major, except for Native Americans where our sample population is quite small. For those who switch, Computer Engineering is the most popular destination within Engineering for Asian, White, and Hispanic males. Industrial Engineering (IE) is the most popular second choice for White females, Black males, and Black females. Populations of other subgroups have less than 5 students switching to another engineering destination.

EE matriculants are a successful group among engineering matriculants. As shown in Table 4 for populations with sample sizes greater than 10, EE matriculants graduate in six years in engineering at higher rates than all engineering matriculants. Asian women show the greatest difference: 69% for EE matriculants and 62% for engineering matriculants. White women, Hispanic men, Black men and women are all have differences less than 2%. The only exception to this is White males who graduate at equal rates. This suggests that EE matriculants are similar to all engineering matriculants. Given that this is whole population data, the differences seen here are real. However, more study is needed to determine if they are meaningful for particular race-gender combinations. For example, what is different about Asian women who matriculate in EE versus those matriculating in engineering?

TABLE 3
NUMBERS OF EE MATRICULANTS GRADUATING IN SIX-YEARS IN EE AND ENGINEERING BY RACE AND SEX. ORDERED BY % RETAINED IN EE.

Race & Sex	Number in EE	Retained in EE	Switching from EE to another ENGR	Graduating in ENGR
Asian Female	61	**57%**	12%	69%
Asian Male	350	**52%**	12%	64%
Native-Am. Male	12	**46%**	8%	54%
Black Female	298	**43%**	7%	50%
White Male	1889	**41%**	14%	55%
White Female	203	**40%**	16%	56%
Hispanic Male	98	**40%**	14%	54%
Black Male	646	**38%**	5%	43%
Hispanic Female	10	**30%**	12%	42%
All Female	2359	43%	11%	54%
All Male	1209	41%	12%	53%
ALL	3568	41%	12%	53%

TABLE 4
PERCENTAGE OF MATRICULANTS GRADUATING IN SIX-YEARS IN ENGINEERING BY RACE AND SEX. ORDERED BY DIFFERENCE BETWEEN EE AND ENGR.

Race & Sex	EE matriculants	ENGR matriculants	Difference %EE – %ENGR
Asian Female	69%	62%	**+7%**
Native-Am. Male	54%	47%	**+7%**
Asian Male	64%	61%	**+3%**
White Female	56%	54%	**+2%**
Black Male	43%	41%	**+2%**
Black Female	50%	49%	**+1%**
Hispanic Male	54%	53%	**+1%**
White Male	55%	55%	**0%**

IV. DISCUSSION

Researchers have begun to explore the reasons why women prefer some engineering disciplines over others. Early socialization, influence of parents and teachers, academic preparation and success, work experience and networks have been cited as important factors [46, 47]. Some research suggests that women prefer majors with a clear benefit to society; thus researchers advocate providing meaningful contexts for problem solving and applications to help attract women [48]. However, Hartman, Hartman, and Kadlowec [49] surveyed 83 first year female engineering students in mechanical and electrical engineering and compared them with those in chemical and civil/environmental engineering. They found that background differences, differences in general academic and math/science self-confidence, attributions of success, and expectations about the engineering degree did not account for the differences in proportions of women in the different engineering majors. No statistically significant differences were found between women and men in all majors regarding their expectation that their engineering degree would help them make an important contribution to society. The researchers did find differences in the reported engineering self-confidence of women entering the different majors. "Work needs to be done on raising the self-confidence of other qualified women, so that they too will consider the most non-traditional engineering disciplines." They also call for more research on the persistence of women in these majors. Our work addresses this quantitatively. Further qualitative analysis is necessary to understand the reasons why students matriculate and graduate in EE.

Interesting recommendations for promoting EE for women have been suggested by Hazzan, Levy and Tal [6]. They developed a one-day introduction to EE for female high school students and showed a dramatic change in the students' perception of the field and willingness to study it. They argue that it is important to show prospective students a realistic image of EE including the multidisciplinary nature and its connection to many aspects of society rather than dwelling on EE as an "exceedingly difficult" topic. Such workshops indicate the importance of diversifying images of engineering presented to potential students. For minority students and women students, exposure to similar role models and cultivating potential mentorships are also important. Many universities successfully host summer workshops designed to attract and immerse potential students into the field of undergraduate engineering.

EE is relatively successful at attracting students including women and minorities especially Blacks. This might be related to the large number of electrical engineers so that the chances of students having heard of EE or seen an EE role model are greater than for other engineering disciplines. Qualitative research examining differentiation by engineering major, race and gender is necessary.

V. SUMMARY/CONCLUSIONS

Based on the findings presented here, the trajectories of students matriculating in EE are gendered and racialized. This merits further study to better understand who EE students are and identify potential recruiting opportunities to draw more students into the field. Further qualitative research is needed to understand the reasons behind these enrollment and graduation numbers. This work raises questions for discussion among the EE education community where the input of many is vital to addressing the issues and enhancing the profession.

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Achieving and Sustaining Gender Balance in an Undergraduate Teaching Institution

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Abstract --- **Recruiting and retaining women in the STEM faculty ranks has been a national priority for many years. Recent research, sponsored by the NSF ADVANCE program, was performed mostly by doctoral institutions. However, for small undergraduate universities, the resulting challenges and decision frameworks are likely to be different. The prevalent recommendations need to be re-evaluated and re-interpreted for relevance and applicability.**

Multiple change agents have been identified, but it is believed that the departmental climate most strongly correlates with successful institutional transformation. The primary success factor is a set of formalized processes in: (1) teaching, scholarship and service, (2) mentoring, and (3) leadership. A secondary factor is a faculty support infrastructure capable of fostering collaborations and reducing isolation. A third factor is an introspective capability that broadens the understanding of the issues affecting women ultimately expressed in the form of better policies and procedures.

There is a strong connection between gender progress on the faculty side and improving the pipeline of female students. To effectively intervene on the supply side, it is important to have networking, mentoring and role modeling processes that match student demographics and global sociological conditions. In the case of our University, this requires recruiting, developing and retaining faculty whose principal focus is undergraduate education which is challenging in STEM fields where the traditional emphasis is on research.

Curricular evolution in doctoral institutions is typically driven by emerging trends and technological opportunities while the needs of regional industries and local programs are more influential among primarily undergraduate institutions. As advanced degrees become a professional requirement, baccalaureate graduates will be expected to pursue advanced studies early in their career. Hence, more undergraduate STEM programs will serve as feeders to doctoral institutions. The future supply of graduate students and ultimately faculty will become more dependent on these teaching universities.

This paper describes our specific efforts and successes in the context of an undergraduate teaching institution. We have demonstrated that even with limited resources and no external funding, it is possible to improve the community culture and climate. Tangible strategies and initiatives aimed at improving the climate are presented: (1) administrative leadership commitment, (2) grants and endowments, (3) faculty development resources, (4) workshops that mirror industry successes, (5) early and mid-career planning, and (6) recruiting and retention of female faculty.

Keywords- gender balance; female faculty; recruiting; student retention

I. INTRODUCTION

Recruiting and retaining women in the science, technology, engineering and mathematics (STEM) faculty ranks has been a US national priority for many years [1]-[9]. Recent research, sponsored by the NSF ADVANCE program, was performed mostly by doctoral institutions [10]. However, for small undergraduate universities, the resulting challenges and decision frameworks are likely to be different. The prevalent recommendations need to be re-evaluated and re-interpreted for relevance and applicability.

Our University is a small private undergraduate institution conveniently located among a vibrant array of high technology companies. A key strategic objective of the University is managed growth and improved retention by fostering unique and distinctive programs. The five-year academic strategic plan of the University is to sustain an academic community of scholars who embrace its mission. One element of this strategy is to increase STEM faculty diversity.

The STEM disciplines are primarily concentrated in Engineering and Arts & Sciences (A&S). Engineering supports ten while A&S has seven STEM-related programs with enrollments of about 500 and 170 students, respectively. These programs vary widely in size/demographics and gender diversity (student as well as faculty). The STEM matrix in Table I shows program enrollment and gender mix for the fall 2009 semester.

There is a strong connection between gender progress on the faculty side and improving the pipeline of female students. To effectively intervene on the supply side, it is important to have networking, mentoring and role modeling processes that match student demographics and global sociological conditions. In the case of our University, this requires the principal focus of faculty to be undergraduate education, a challenge in STEM fields where the traditional emphasis is on research.

TABLE I. STEM PROGRAM MATRIX

STEM Program Matrix AY 2009-10

Degree	Engineering Programs	Enrollment /Female/%
Bachelor of Science	Acoustical Engineering	34/06/17
	Biomedical Engineering	38/13/34
	Civil Engineering	66/07/11
	Computer Engineering	34/02/06
	Computer Engineering Tech.	24/06/25
	Electrical Engineering	53/01/02
	Electronic Engineering Tech.	30/02/07
	Environmental Engineering	04/02/50
	Mechanical Engineering	140/17/12
	Mechanical Engineering Tech.	52/07/13
	Arts & Sciences Programs	**Enrollment /Female/%**
	Biology	74/48/65
	Chemistry	23/05/22
	Computer Science	38/03/08
	Mathematics	14/03/21
	Physics	08/00/00

II. ADVANCE RESEARCH FINDINGS

The National Science Foundation's (NSF) Advancement of Women in Academic Science and Engineering Careers (ADVANCE) program is a national strategy designed to broaden participation in the STEM workforce [10]. The long-term goal is to advance the status of women in academic science and engineering, and NSF more specifically describes its objective as:

"…to increase the representation and advancement of women in academic science and engineering careers, thereby contributing to the development of a more diverse science and engineering workforce. ADVANCE encourages institutions of higher education and the broader science, STEM community, including professional societies and other STEM-related not-for-profit organizations, to address various aspects of STEM academic culture and institutional structure that may differentially affect women faculty and academic administrators. Since 2001, the NSF has invested over $130M to support ADVANCE projects at more than one-hundred institutions of higher education and STEM-related not-for-profit organizations…"

There are over 3,500 higher-education institutions in the United States, most of which offer one or more STEM programs. NSF contracts have historically been concentrated in the Top 100 research universities. Table II shows ADVANCE funding which mirrors this trend with the exception of 2003 where a majority of the awards were directed towards Tier 3 institutions. In three of the four cohort years, Top 100 universities were predominant.

TABLE II. NSF ADVANCE AWARDS

University or College	Ranking	UGs
Hunter College	Masters – North, 51	16 k
Univ. of Colorado	National, 79	26 k
Georgia Institute of Tech.	National, 35	12 k
Univ. of Michigan	National, 25	25 k
New Mexico State	National, 4th tier	13 k
Univ. of Puerto Rico	-	
Univ. of California	National, 44	21 k
Univ. of Washington	National, 42	28 k
Univ. of Wisconsin	National, 38	30 k
Case Western Reserve	National, 41	4 k
Univ. of Montana	National, 3rd tier	10 k
Columbia Univ.	National, 3	7 k
Univ. of Rhode Island	National, 3rd tier	12 k
Univ. of Alabama	National, 3rd tier	11 k
Univ. of Texas	National, 4th tier	17 k
Kansas State Univ.	National, 124	19 k
Utah State Univ.	National, 3rd tier	13 k
Univ. of Maryland	National, 3rd tier	9 k
Virginia Tech	National, 71	22 k
Brown Univ.	National, 14	6 k
California State Poly.	Masters – West, 31	19 k
Cornell Univ.	National, 12	14 k
Iowa State Univ.	National, 85	20 k
Rensselaer Poly. Institute	National, 44	5 k
University of Arizona	National, 96	28 k
University of Illinois	National, 3rd tier	15 k
Univ. of North Carolina	National, 4th tier	17 k
William Marsh Rice Univ.		
Michigan State Univ.	National, 1st, 71	36 k
North Dakota State Univ. Fargo	National, 3rd tier	10 k
Northeastern Univ.	National, 1st , 96	12 k
Ohio State Univ. Research Foundation		
Purdue Univ.		
Rutgers Univ.	National, 1st , 64	27 k
Univ. of Nebraska Lincoln		
Washington State Univ.	National, 1st,116	20 k
Wright State Univ.	National, 4th tier	12k

The principal strategic activities undertaken by the ADVANCE institutions were to: (1) improve workplace climate, (2) attract and retain female faculty/students, (3) transform departments, (4) stimulate partnerships in scholarship and teaching, (5) measure and report progress and (6) promote advocacy and active research collaboration. A comparison of the projects reveals many similarities across the spectrum of awardees structured along the following lines:

- Comprehensive self-study
- Basic research on gender topics
- Visiting scholars
- Coaching constituencies
- Best practices training from industry
- Focused workshops and conferences
- Policy and procedure modification
- Collaborative research incentives
- Networking, mentoring and role modeling
- Department transformation
- Position funding (ADVANCE chairs)
- Leadership development
- In-house gender equity endowments
- Interventions for faculty
- Balance work-life issues
- Recruiting initiatives

While multiple change agents were identified, the departmental climate is believed to most strongly correlate with successful institutional transformation. The leading departmental success factor is a set of formalized processes in: (1) teaching, scholarship and service, (2) mentoring, and (3) leadership. A secondary factor is a faculty support infrastructure capable of fostering collaborations and reducing isolation. The third factor is an introspective capability that broadens the understanding of issues affecting women ultimately expressed in the form of better policies and procedures.

Now that the projects for Cohort 1 are completed, researchers are beginning to assess the degree of transformation that has been and will continue to be achieved. Transformations of this sort are likely to occur over a span greater than five years [11]. To be sustained, some level of institutionalized funding will be required. The issue of sustainability was addressed by Litzler *et al* [12]. where seven of the nine colleges and universities that received funding in 2001 were surveyed. The purpose of the work was to gauge the degree of institutionalization as measured by the presence of stable funding to continue one or more successful ADVANCE project elements. The three main findings were: (1) leadership change at the top decreased the likelihood of success, (2) there was no direct correlation to the level of state funding, and (3) transformation occurred in degrees based on support, duration, diffusion, and advocacy. From our perspective, the most interesting point was the success of state universities in the mid-range of financial assistance. Those in the lower and upper scales were unable to establish and maintain internal efforts. For small undergraduate teaching institutions, it appears that funding constraints may block progress even in the presence of perceived value and support at the top.

III. INTERNAL RECRUITING EFFORTS

On the engineering side of STEM programs at our University, there are currently 23 full-time faculty teaching core technical courses. In 2005, there were three female faculty members, one in each of three departments. One was tenured and had achieved the rank of full professor. Two others were assistant professors and on tenure-track. The total number of faculty has remained relatively constant since 2005 and is not projected to increase. In support of the University's mission, values and strategic plan, the focus in STEM faculty diversity is to recruit and retain women as new positions and vacancies arise.

Since 2005, six faculty searches have taken place to fill open engineering positions. In three cases, we were successful in recruiting a female. To date, all three have been retained as assistant professors and are progressing on tenure-track. Consequently, in the last five years, the number and percentage of female engineering faculty has doubled from 3 (13%) to 6 (26%). Meanwhile, of the two incumbent female faculty members, one has been tenured and promoted to the rank of associate professor. She was also appointed department chair, while the other is eligible for tenure and promotion this academic year. Table III summarizes our recent progress in improving gender balance within the engineering faculty ranks.

TABLE III. FACULTY RANK GENDER PROGRESS

Engineering Faculty		
23 total faculty in civil, electrical & mechanical engineering		
Female Faculty	**Academic Yr.**	
	2005-06	
	No.	**%**
Tenured/tenure-track	1/2	4/8
Rank: Assistant/Associate/Full	2/0/1	8/0/4
Chair: Civil/Electrical/Mechanical	0/0/0	0%
	2009-10	
Tenured/tenure-track	3/6	13/26
Rank: Assistant/Associate/Full	4/1/1	17/4/4
Chair: Civil/Electrical/Mechanical	0/0/1	33%

In recruiting six faculty from 2005-09, the Provost's Office assisted the departments by paying for additional ads to increase the number of women applicants. While the gender mix of the overall candidate pool is not known, women were finalists and granted campus interviews in five of six cases. It appears that the percentage of women who applied was higher than their representation in the national undergraduate ranks. The growth in doctoral graduates in recent years has been attributed to temporary visa holders, many of whom choose to remain in the US, including many women. This increases the female candidate pool and enables faster progress towards gender balance. Of the last six female hires dating back to 1992, five were international Ph.D. graduates who received their terminal degree domestically.

In the last six faculty searches since 2005, the committees chose one or more women as finalists five times. It is interesting to note that in none of the cases was a woman ranked first. However, as the leading candidates dropped out, the women rose to the top and some were ultimately hired. In one case, a promising female ended up second to another and would not have received an offer. The Provost's Office agreed to create an additional position to seize the opportunity.

Given this recent success in adding female faculty, our capacity to leverage their presence in student recruiting has been strengthened. We have experienced the impact of women as active role models in open house events, orientations and advising. Beginning in 2006, the number and percentage of women undergraduates entering the College has steadily increased with the most improvement in biomedical, civil and mechanical engineering. In prior years, female enrollment was flat.

IV. INTERNAL FUNDING OPTIONS

To create a successful track record of scholarship, new engineering faculty need to establish a technical research focus including journal publications and a supporting network of peers and collaborators. Start-up packages, customarily offered by research institutions, are not provided; consequently, new faculty must aggressively pursue funding from internal and external sources. In a primarily undergraduate institution with heavy teaching loads, the most effective research strategy is to integrate and leverage grants that include course releases. To assist with the research, it is also important to cultivate a cadre of undergraduate and graduate students in a non-Ph.D. environment.

The University offers a number of internal research and pedagogical grants, fellowships and prizes. This pool of funding is an effective way for all faculty to initiate work prior to receiving support from external sources. While awards are for the most part modest and the work must be accomplished within one academic year, they have been persistent and stable line items in the budget over time. The specific internal opportunities accompanied by a brief description are listed in Table IV. A high number of female engineering grantees have received awards over the last eight years. For example, the Greenberg grant has been in place since 2001 and engineering faculty have won four times; three of the recipients were female.

TABLE IV. INTERNAL GRANTS FOR FACULTY

Internal Grant Opportunities		
Name	**Female Awards**	**Description**
Vincent B. Coffin grant	3	Offsets the loss of income for summer teaching obligations in order to have release time to engage in substantive scholarly or creative work
Summer stipend	2	Offsets the loss of income for faculty from summer teaching obligations to engage in scholarly or creative work
Faculty Center for Learning & Dev. Grant (not active)	3	Supports course re-design to make it more appealing and effective
Greenberg Junior Faculty grant	3	Supports high-quality scholarship for faculty members just beginning their careers
Belle K. Ribicoff Junior Faculty prize	0	Awarded to one junior faculty each AY. A recipient of one of the above awards from the prior 3 years is chosen as the Belle K. Ribicoff Professor for 3 years, with a stipend to pursue course development, artistry, research or scholarship
Innovations in Teaching award	1	Recognizes innovative assignments and activities that positively impact student learning
Engaged Learning Fellow	1	Supports implementation of an engaged learning strategy including but are not limited to service learning, problem-based learning, and learning communities
International Center Faculty grant	1	Supports internationalization of course content, develop a study abroad course, partake in a faculty development seminar, present a paper, or conduct research
WELFund grant	6	Supports initiatives to enhance women's education and leadership both on and off-campus by awarding grants to innovative projects designed with women or girls as the primary beneficiaries

The funding sources shown in Table IV support the community as a whole with some emphasis on tenure-track faculty. An exception is the Women's Education and Leadership Fund (WELFund) which has evolved into the primary means for advancing gender-based initiatives irrespective of academic status. Established in 2006, the purpose of WELFund is to: (1) enhance the education of women, (2) advance women as scholars and as the subject of scholarship, (3) cultivate and sustain women's leadership skills, and (4) increase awareness about women as individuals and in communities. WELFund was established as a legacy to Hartford College for Women, a single gender institution affiliated with the University of Hartford in its final years, and the primary source of WELFund grants is the remaining endowment of this college. An eleven member board, composed of regional leaders, both women and men, establishes priorities, reviews application materials, and decides which proposals will be supported. In the nearly three years since its founding, the program has funded 62 different projects. Individual grants have ranged from $2,000 to $10,000, and any student, staff or faculty may apply, regardless of gender.

Faced with limited financial resources, the University community has come to rely on WELFund to enable projects in the following areas: (1) faculty research, (2) support for student research, (3) professional development, (4) STEM best practices, and (5) leadership initiatives. For example, three recent grants funded engineering research by female faculty in the areas of acoustics, transportation, and microprocessors, and each project included female undergraduate students. Thus, faculty have been able to secure a base level of support to initiate and grow research interests while simultaneously attracting female student collaborators. The obvious benefit for faculty members is to publish and present work beyond what would normally be possible (e.g., one conference per year). For most students, this is their first opportunity to participate in research, write peer-reviewed content and network with professionals in the field.

In addition to seeking support for research collaborations, engineering faculty and staff have been aggressively pursuing WELFund monies for recruiting and retaining female students. One of the projects created experiential modules of various engineering specialties targeting high school girls. Each of the modules emphasized the capacity of engineers to improve lives, an effective strategy to engage female students. Another grant supported a University-magnet high school collaboration; the outcome will be a two-week summer day camp to introduce incoming high school girls to STEM fields. Further, an after-school program was implemented to discover best practices in mixed gender situations using the comparison of a single gender afterschool program. Although it is hard to measure the quantitative impact of these efforts, our appeal to female students has been enhanced, and the faculty/staff continue to energetically pursue other promising avenues.

WELFund is one of the only organizations identified in the country to provide direct financial support to faculty, staff and students. Female students received funding to create and sustain SWEET Day (Society of Women Engineers Educating for Tomorrow). SWEET Day has become a highly successful event for prospective students and their parents that encourages young women to consider engineering as a career. Workshops, informative guest speakers, and a tour of College facilities help expand the image of the engineering profession as a positive force in improving quality of life. The attractiveness of our STEM programs has been improved and participants are now more likely to apply.

A female engineering student was awarded two successive grants to support a collaborative project, "Water for Abheypur," between the University, Engineers Without Borders (EWB), and the Indian village of Abheypur. In the first project, a multidisciplinary team with two female students installed a solar powered ground water pump and tanks. The second project funded the design and implementation of a rooftop rainwater harvesting system. The system provides a source of water during the monsoon season when the solar pump is not effective. Subsequent surveys among students revealed a high level of interest and support for these projects, and what was originally an engineering effort has expanded to include sociologists from the College of Arts and Sciences and design students in the Hartford Art School.

WELFund has supported a series of associations and activities that connect women students with staff, faculty, and alumnae, providing opportunities to discuss work/life balance, health, financial acumen, and more. In addition, an outside speaker series, open to both University and high school students, invites accomplished women scientists and engineers such as Jocelyn Bell Burnell**,** British astrophysicist, to present their experiences in preparing for a STEM career.

In 2008-09 WELFund began a pilot program, the Laura Johnson Initiative for Women Leaders,and brought together fifteen faculty and staff for monthly professional development workshops. Its aim was to provide the knowledge, skills, and networking necessary to facilitate both career enhancement and advancement. An outgrowth of this initiative is the Leading Forward leadership program, designed by the first faculty-staff cohort to provide a similar cohort experience to female graduate students. A series of sessions explore individuals' leadership styles, goal setting, and communication strategies. Each participant is provided a mentor who is a member of the University community. Both of these programs have been designated as on-going offerings of WELFund, and will have a substantial impact on the University’s culture for women.

V. DEPARTMENT CLIMATE

As mentioned previously regarding ADVANCE findings, the department climate most strongly correlates with successful institutional transformation. The leading success factors are formalized processes in: (1) teaching, scholarship and service, (2) mentoring, and (3) leadership. The faculty authors, both department chairs, received a WELFund grant to facilitate leadership mentoring and professional development for two junior female faculty and themselves. Junior faculty were provided an opportunity to address future research, educational, and academic challenges. The senior faculty focused on academic and positional leadership activities. The grant was designed to create a more systemic approach to mentoring and to foster a supportive climate in each department.

In our College, new tenure-track professors are assigned a senior faculty as a mentor. However, mentoring for leadership is not part of peer mentoring as we know it. The mentoring literature [13] has shown that faculty can benefit from multiple mentors; therefore, a good mentoring process should create an environment where 'giving and receiving guidance are embedded in the values and norms of the organization [14].'

New faculty members bring fresh perspectives to their respective programs, departments and colleges. They are typically well-suited to contribute in the following ways: currency in educational technology, developing new/improved courses, integrating topical threads across the curriculum and becoming a change agent. While the benefits of strong educational leadership are apparent, faculty who contribute in this area often do not receive appropriate recognition. Contrary to this practice, both junior faculty were successful in receiving internal grants to evaluate new classroom technology. The results were presented in the form of a workshop to our departments.

Both junior faculty have established a research focus including a track record of publications and a network of peers and collaborators. Their challenge in the area of technical leadership is to grow research funding and a local network of academic and industrial partners. Each was successful in obtaining research funds during their first academic year. One received an external grant, in part due to the mentoring by an assigned and motivated faculty member in the same program. Such proactive and quality mentoring is not common. Ownership of tenure-track success within any department is less than desired. The likely causes are heavy teaching and service loads, exacerbated by a mentor's need to sustain their own research area. Consequently, senior faculty exhibit insufficient professional interest in junior faculty development. This is somewhat buffered at the University level by a 'new faculty' first-year orientation. However, a mentoring gap continues to exist for junior faculty and associate professors.

Most engineering faculty do not seek opportunities in academic leadership. Our two departments have collectively five positional openings and often a single faculty member holds more than one because of insufficient interest or skills. Junior faculty have become active in open house events and first-year orientation sessions, and ultimately will have to decide what role(s) to accept. For example, supported by targeted funds within the author's WELFund grant, one went to leadership training while the other attended a first-year student retention workshop.

The positional leadership challenge addressed by the faculty authors was to improve the balance of their research efforts and administrative duties. The solution was to make greater use of delegation within the departments and to set personal goals that strengthen research efforts. Subsequently, the faculty authors received a total of 6 grants/awards within one AY. In addition, a number of technical and pedagogical papers were published and all grant participants attended multiple conferences over and above the norm, which is one per faculty member.

VI. PRIVATE UNIVERSITY-PUBLIC PURPOSE

Curricular evolution in doctoral institutions is typically driven by emerging trends and technological opportunities while the needs of regional industries and local programs are more influential among primarily undergraduate institutions. As advanced degrees become a professional requirement, baccalaureate graduates will be expected to pursue advanced studies early in their career. Hence, more undergraduate STEM programs will serve as feeders to doctoral institutions. The future supply of graduate students and ultimately faculty will become more dependent on these teaching universities.

To this end, the University has taken steps to strategically address our emerging role in the graduate pipeline by formalizing a shared values statement 'Committed to Community':

"At the University of Hartford, we are committed to community. We are an academic community that values integrity, curiosity, creativity, excellence, responsibility, and accomplishment. Enriched by our diversity and our engagement with one another, we take pride in our shared traditions and experiences. We are dedicated to building a culture that respects all of its members and celebrates their contributions as we work together to strengthen our community [15]."

In the spirit of the above values, a presidential commission on the status of women was recently formed to expand the opportunities for all women and men on the faculty and staff. Our College is well positioned to meet the challenge with recent female faculty hires as well as a healthy array of student-oriented activities including SWEET Day, EWB and K-12 engagements. We have demonstrated that even with limited resources and no external funding, it is possible to improve the community culture and climate. The recent spike in female engineering enrollment may very well be an early indicator of future success. In some respects, the positive changes we have made may be more sustainable since these were obtained at the expense of internal resources.

VII. CONCLUSIONS

Significant progress has been made within the engineering disciplines of our College in improving gender balance. The community has relied upon an ensemble of rather modest internal grants, awards and prizes. Given the relevance of its stated mission, the WELFund grant has become the primary vehicle for supporting many gender specific initiatives. Within the past five years, recruitment and retention of female faculty was successful. During this period, one female faculty was promoted and tenured, and the other is eligible soon. In addition, three new female faculty were successfully added, one in mechanical and two in electrical, both areas that typically have the lowest representation compared to other engineering fields.

Meanwhile, ADVANCE grants have funded five-year transformation efforts across four cohorts totaling 38 institutions. The majority of the funding was awarded to large research universities. The projects for the first and second cohort groups have been completed, and the challenge these institutions now face is how to continue the more successful activities, especially those that require stable financial support, well into the future. Research designed to measure the degree of positive transformation achieved, as well as the level of recurring internal funding after the grant ended, is beginning to be published. It will require several more cohort cycles and years for a clear picture to emerge and be disseminated.

The scope and breadth of effort afforded by ADVANCE goes far beyond what we have been able to accomplish. Many of the best practices that have or will stem from the broader impacts cannot be implemented at our University given the internal resource constraints. It is likely that some incremental improvement in gender balance will continue to be made. In some ways, this progress may be more sustainable because the value, ownership and investment stems from within. For a truly transformational change, external resources will be needed, and preliminary work along these lines has begun. In parallel to this activity, we will continue with efforts that leverage our internal capabilities and current momentum to build on recent successes.

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Spirit

University of Stuttgart's Life-Cycle-Based Gender-Mainstreaming-Concept

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Abstract— **In spite of social and political efforts to achieve equal opportunities, women remain a minority in natural sciences, technical and related fields. We hereby present the gender concept of the University of Stuttgart. First, the steps for promotion of female students within natural sciences and technical fields are developed.**

Keywords-gender concept, female academic education, diversity studies, women in natural sciences and engineering

I. INTRODUCTION

Despite comprehensive social changes and political efforts to achieve equal opportunities, women remain a minority in the natural sciences, technical study fields and the corresponding occupational fields. This paper presents the complete gender concept of the University of Stuttgart. First, the steps for promotion of female students and women within the natural science and technical fields have to be developed. Female underrepresentation in science and the demand for equality of the sexes have become a vital aspect of the ongoing reform discussions. A special look should be taken at the education-economic perspective, as well as the aspect of quality assurance and the capability to be innovative [1, 2]: –

- The underrepresentation of women in scientific and technological fields has implications on design, quality and diversity of products. In fact, creative innovations cannot be "all-inclusive" without the inspiration of women: products might be designed faulty because their usage options were only viewed under considerations based on requirements of special groups (e.g., airbags, artificial heart valves, voice recognition systems [3].
- The absence of women from certain technological fields poses a hard challenge for industry and economy: the demand of qualified specialists cannot be satisfied by men willing to pursue an academic education [4].. The existing loss of interest by men in technical and engineering subjects intensifies the challenge [5]. Moreover, demographic development in Germany and global competition only augment these challenges.
- Technical disciplines graduates are filling important jobs in our society, which are characterized by fields of responsibility and extensive influence. Technical authorities are a key factor for the shaping of our society [6]. The underrepresentation of women in these fields is a major drawback to equal participation efforts.

Indeed, there are numerous single initiatives aimed at "breaking down the gender-gap" in German universities, each engaged either by different single persons, offices for equal opportunity, as well as individual professors, centres, or initiatives in single institutes. Due to the lack of a comprehensive strategy, such efforts often lose consistency, continuity and transparency, which often leads to a "twofer" for some target groups, while other arrangements and initiatives are missing. Communication and information campaigns aimed at reaching a broad group, creating a common understanding of the challenges and requirements are an exception. Universities should coordinate existing and successful measures in order to achieve better results, aiming for a stronger gender master plan.,

- that comprises the full life-cycle from kindergarten to professorship with leadership function,
- with single steps that aim to make a seamless, coordinated transition between different measures possible,
- that incorporates all areas (education, research and organization)
- and that includes a concept of family-friendly policies for all members of the university.

The female professor program is a characteristic component of the gender master plan of the University of Stuttgart.

The underrepresentation of women in technological fields becomes particularly visible in predominantly scientifically and technologically aligned universities like the University of Stuttgart, where a large percentage of future scientists and engineers are trained. These universities are in charge to overcome the gender gap in the technological disciplines, justifying a broad and early commitment to gender management. Additionally, women are nominated as top position holders of technical disciplines in order to increase diversity in research and education presenting female role models to new generations.

II. SITUATION-(DEFICIT-) ANALYSIS

Girls and women are still underrepresented in technology-oriented programs. The University of Stuttgart is well aware of these challenges, being a long term driving force to raise the percentage of females. The structure and development plan SEPUS of the University of Stuttgart defines measures; each of them successfully proven. However, the University of Stuttgart neglects a master plan that connects all measures and sustainable networks that build on and support each other. The concept presented here pursues the goal of integration and sustainability of measures. The University of Stuttgart is a fully profiled university oriented towards technological and scientific programs, and the concept of equal opportunity is aligned with this profile. Therefore, the focus is on the recruitment of women into technical disciplines. They are initially acquired for scientific and technical degrees, then promoted, depending on their talents, and supported on their "job ladder" inside or outside the university. The objective is to boost the percentage of female students in scientific and technical disciplines from currently 20% to 30% (within the entire university from 34% to 40%) and the rate of young female scientists from 18% to 30% (within the entire university from 21% to 30%). The target in these disciplines is set for an increase of female professors from 6% to 10% (same within the entire university) within the next five years. Furthermore, 30% of the professorships have to be newly appointed until 2012. Therefore, a considerable increase is possible.

Baden-Württemberg is striving for a long term increase of the quota of female professors to 30% (defined by the head of the Office of Scientific and Technological Affairs, Frankenberg).

III. OBJECTIVES CONCERNING DIFFERENT TARGET GROUPS

Chapter IV.A describes the different measures to be implemented within the framework of the gender master plan of the University of Stuttgart in detail. This chapter summarizes the most important foci from the catalogue of measures concerning addressing the different target groups:

- Increase percentage of women in top scientific positions

The incompatibility of a scientific career and family is still a major reason for women to distance themselves from the former. To address this challenge, the University of Stuttgart is working towards improving the surrounding circumstance to unite a scientific career with family life. The intention of sufficient child care offers, a family friendly housing situation, the adjustment of study and examination regulations and development of alternative work schedules are supporting this goal. Another important point considering the encouragement of women in leading scientific positions is the inclusion of the career planning of their partners (Dual Career).

The University of Stuttgart is aiming to increase the ratio of female professors to 10% according to their structure and development plan. To create the long-term framework for this goal, the University of Stuttgart is developing a package of measures. Especially qualified female students and young female scientists are provided with individual sponsorship and a structural framework to improve the compatibility of scientific career and family. The financial support through scholarships is seen as of similar importance as the personal support through formal and casual networks and the acquisition of career-furthering qualifications. Versatile cooperation with regional companies put the University of Stuttgart in the unique position to offer attractive choices within the industry and economy to partners of female researchers.

- Career and personal development for young female scientists

The next important point is the phase between academic studies and the beginning of a scientific career: that is the point where future scientists should be made aware of the existing career options in order to begin to develop their career-strategies. They need to gain access to networks and acquire leadership and management qualifications. Community building between students and young scientists is fostered by employing comprehensive measures within the single institutes and creating positive role model, initiating a regular exchange of experience between successful young scientists and female entrepreneurs.

In order to raise female students and young scientists, it is important to create a supportive living environment and to present attractive employment opportunities to their partners, in short, offering Dual Career Options as early as the qualification phase. To achieve this goal the University of Stuttgart has set out to earn the certificate of "‘family friendly university"’ awarded by the Hertie-Trust.

- Acquisition of female students in the natural sciences and technological disciplines

A central condition is the awakening of enthusiasm for natural sciences and technology to foster the election of a scientific or technologically oriented field of study later in life. The University of Stuttgart has build a package of measures that incorporates the education of teaching staff, as well as considering research of gender sensitive deployment of toys and the creation of an academy for younger children. Furthermore, the University is compiling effective public programs - female students are given an age-based understanding of natural and technical questions. It is for such purposes, that existing programs like the Girl's Day have been expanded and new choices like the Technology-Camp were developed. Female students can use their vacation time to research exciting scientific and technological topics.

In order to help a girl on the decision of choosing a technological or scientific program of studies there is the offer of a trial course, as well as a program to support them from the last year of high school to the first semester at the university. In addition to the program "Try the University", girls in the last year of high school are being offered the full curriculum of available bachelor degrees and are enabled to collect credits towards their future studies.

IV. IMPLEMENTATION OF THE CONCEPT SPIRIT

The concept is following a life-cycle model. The target groups are girls and women which are accompanied from kindergarten to professorship by multifaceted package of programs: The single activities are weighted differently depending on the phase of life, build on each other and are interlocked. This ensures that measures exist for each state of the life cycle that aim towards a goal and support the progress towards the next phase. Special weight will be put on the systematic advancement of female migrants due to the fact that their requirements are defined by a different process of socialization compared to women without a migration background.

A. Measures for Each Scope of the Life-Cycle:

1. Gender Sensitivity Training Courses for Educators

Measures have to be taken already in kindergarten to ensure the best possible equal upbringing of girls and boys. |Sparking children's interest in natural and technical questions requires careful planning of all educational activities. To improve this concept the University of Stuttgart designs, prepares and implements gender- and diversity- sensitive scientific and technical professional training for educators. Evaluation and counseling is provided by the Institute for Social Sciences.

2. TechToy

Gender and diversity sensitive engineering toys that are accepted and appreciated by both sexes are necessary to awaken the enthusiasm for the natural sciences and engineering early and across both genders. The University of Stuttgart plans to apply a main research focus on the development of gender sensitive engineering toys. A co-operation of different chairs of engineering, the Institute of educational science and psychology, and the institutes for social sciences, technology and environmental sociology [7] will carry this research focus. This concept is built on the preparations for the initiative "Wissensfabrik" (knowledge factory). The University of Stuttgart will soon join this initiative - one of the first universities to do so. A pedagogic concept is being developed to allow for a meaningful use of the toys in pre-schools, schools and families. Such a concept could look similar to – the extremely successful – Roberta- teaching materials of the Fraunhofer IAIS for LEGO Mindstorms robot building (a Roberta Regional Centre is currently being build up and developed at the Institute for IT Service Technologies).

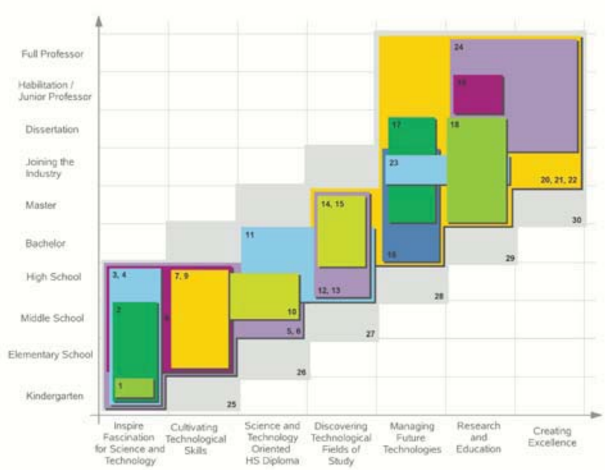

Figure 1. Life-cycles from kindergarten to professorship

3. Exhibition Team University of Stuttgart (ETUS)

The University of Stuttgart build a professional team that will focus on public relations with specific target groups. The field of responsibility for this team also includes the development of effective publicity programs for events at the University of Stuttgart including the Day of Science ("Children's-Campus – Program for young researchers"), as well as Technology exhibitions like the "Land of Ideas" or the "Cebit". During this process, programs will be prepared to fit the different target groups of preschool age, elementary school, junior high school, secondary school age, and for teachers. This project can build on the experience of the Student Counseling Centre and of the marketing office.

4. Rent-a-Scientist & SchoolgirlUni

This is a project in which pre-schools and schools are offered possibilities to "rent" (female) professors or (female) research staff of the University of Stuttgart. They visit the educational institution and answer questions from the fields of science and engineering with age group specific lectures and demonstrations. In reverse, the University of Stuttgart offers (female) students the possibility to come to the university to get to know it "from the inside" (student/schoolgirlUni). To ensure the success of such events a pedagogical concept is drawn up and staff members are trained (pedagogical mentoring by the Institute of educational sciences and psychology). The concept also addresses culture-based conflicts of interests – especially relevant for pre-schools and schools with a high ratio of children from migrant families. The measures 4–6 and 8–10 are part of the University of Stuttgart Young Academy which is currently being implemented.

5. Girls' Day

The University of Stuttgart has been participating in the mono educational Girls' Day for several years. Girls are invited to the university to have a look at the different scientific and technical areas. Specialized subjects from different departments are being prepared to spark the girls' interest. In this regard the girls have the possibility to try the experiments also on their own. The program will be further developed in the coming years and expanded inside of the university through the integration of more faculties and considering culture-specific differences in interests and approaches.

6. Partner Schools

Direct connections to partner high schools improve the cooperation between schools and universities. Common activities give female students a chance to gain some early insights into research and education at the universities. Such measures may help to facilitate the transition from high school to university, as well as the choice of a course. They should further benefit from the close cooperation with the successful "Mine-Mint"-Network. The continuing initiatives involving the Institute for Hydraulic Engineering, the Department of Physics, the Department of Chemistry, as well as the Department of Computer Science, Electrical Engineering and Information Technology and the freshly initiated cooperation with the "Landesgymnasium für Hochbegabte in Schwäbisch-Gmünd" shall be continued and further expanded.

7. Gender Sensitivity Training for Teachers

This training course is designed to enhance the skills of teachers in gender and diversity sensitive didactics for teaching technological or scientific courses. As the result of both formal and family education, girls are interested in different questions than boys. The course develops guidelines based on concrete examples to help teachers create a sense of fascination and adventure concerning science and technology in students. These courses are supported by the competency of the Institute for Social Sciences. The University of Stuttgart takes advantage of the unique situation created by the restructuring and modularization of the academic education of teachers in Baden-Württemberg to enhance the competencies of teachers in training for gender sensitivity. Current plans allot 6 credit points for this field.

8. Technology-Camps

Technically-oriented summer camps teach modern science in a hands-on approach. These "Technology Camps" present selected current topics from the fields of research and education at the University of Stuttgart in high school level lectures and experimental labs. High school and university students research interesting topics from the natural and engineering sciences in close cooperation with professors. These summer camps expand upon the already existing summer break programs offered by the University of Stuttgart (Stuttgarter Forschungsferien). The university can build on experiences gathered in the (Nanocamp, Faculty for Civil- and Environmental Engineering). Future summer camps will be offered as mono or co-educational. Mono-educational summer camps will make participation easier for female students from families with a migration background. The SPIRIT program plans to offer stipends for students from financially weaker families through the integrated foundation.

9. TechnoClub "Test your University"

The TechnoClub offers single workshops and one-semester courses for female high school students, held at the university. Lectures and labs held by members of the university are designed to familiarize high school students with the daily life at the university. These courses include a lab for Robo-Rescue and courses for electronics and soldering. Special attention will be given to culture-specific variations in interest and approaches in support of the main focuses 4, 5, and 8. The courses offered in the TechnoClubs are created by a representative cross section of all institutes within the university and are centrally coordinated. This mono-educational concept is based on a long running and successful program, "Try the University" ("Probiert die Uni aus").

10. Studium Experimentale

The "Studium Experimentale" presents several different approaches to familiarize students with the University of Stuttgart and the different programs offered. First of all, high school students are offered university level courses in a more compact form, including the final exam. This idea is based on the "SchülerStudium" at the FU Berlin. If a participating student should decide to pursue a compatible course of study at the University of Stuttgart, they will receive priority in the acceptance process and will be credited with the corresponding credit points. As a result, ties between students and the University of Stuttgart are created early and the transition from high school to university is eased. Secondly, since female students often find it hard to decide on one single technological or scientific course of study, the University of Stuttgart offers one-year courses with access to all available bachelor courses without forcing the student to enroll with any one particular program. The credit earned during this period is fully applicable to any future course of compatible studies. The University of Stuttgart is currently engaged in defining the necessary legal framework (crediting, BAFöG).

11. Mentoring "Transition from High School to University"

The Campus Mentoring Program matches selected university students with high school students to mentor them at the end of their high school and the beginning (first few semesters) of their university education. The mentors help the students adapt to the daily routine at university. The students will be gradually transferred to an advanced mentoring program supervised by professors as they enter university.

12. Gender Sensitivity in Technologically-Oriented Courses of Study

Technologically-oriented courses of studies and careers are not unattractive to women per se. However, motivation, specific interests, style and strategies of learning, goals and expectations can differ significantly from those of young men. The University of Stuttgart, under the leadership of the vice rector for academic affairs, will create concepts and guidelines for gender sensitivity in all courses of studies, taking advantage of the opportunity offered by the restructuring of all courses of studies, including their content, to the new, modular bachelor/master system.

13. New Technologically-Oriented Programs

Quite often female students fail to feel attracted towards the existing curriculum of engineering and natural science programs. The main reasons are that women do not see the social relevance and/or that they are worried whether their interests and talents qualify them to pursue studies in these fields. The Bologna-Process offers a unique opportunity to create new and reorganize existing programs. The University of Stuttgart is planning to implement a number of new programs addressing the specific interests of female students. These programs will build on the experience from the Galilea-Project at the TU-Berlin (www.galilea.tu-berlin.de, already existing cooperation [8–14]. The first two programs are already being designed (Renewable Energy and Medical Technology). The Galilea-Programs are characterized by a high degree of flexibility in the early choice of courses, as well as socially relevant, interdisciplinary foci.

14. Diversity Studies & Technology Management

It is necessary to understand the role of female engineers and scientists, including their special contributions and unique potential, to attract more women to studies and careers in the technological fields. To address these requirements, the University of Stuttgart is planning to create a program for diversity studies in the engineering sciences with a focus on technology management. The courses offered in the program will be credited as minors or mandatory elective courses in the engineering, economics, scientific and social studies programs, strengthening the impact of gender and diversity studies in the existing programs.

15. Program for Stipends: "Opportunity"

Stipends provide a means for direct promotion of talented students. As such, it is a tool well suited for supporting students from financially weaker families. In addition, they create social networks between the recipients and bring them into contact with prospective employers (often former recipients or even founders of the stipends). The University of Stuttgart plans to create specific stipends for female students of the natural sciences and engineering in close cooperation with successful regional companies and research institutions and with the European Social Fond, ESF. This increase in cooperation will further strengthen the regional economy. The "Opportunity" program complements the existing stipends (stipends for PhD students under the "Landesgraduiertenförderungsgesetz", Schlieben-Lange und Margret von Wrangell Programm).

16. Femtec Region Stuttgart

The low ratio of women in positions of leadership within the economy and the resulting perception of a lack of career opportunities has a direct, negative impact on the motivation of female students. The University of Stuttgart is planning to expand the existing cooperation with the successful Femtec program and its associated career building program. Femtec is a unique network of leading technical universities and successful international companies. The University of Stuttgart has been a member of the Femtec network since 2005. The aim of the program is to strengthen the cooperation with the regional economy. The associated career building program teaches leadership qualifications easing the transition to a successful, professional career. The University of Stuttgart is already represented on the advisory board of Femtec.

17. Entrepreneur Initiative SPIRIT

Based on the experience gathered in the joint project "Erfolgreich ist weiblich!" (in cooperation with the TTI GmbH, started in February 2007), the University of Stuttgart is creating an informational and consulting offer for students and post graduates, as well as the alumni of the University of Stuttgart who wish to found their own start-up. This network will provide gender specific support within and beyond the boundaries of the university itself.

18. Mentoring for Women in Science and Research

In addition to good qualifications and grades it is often the contact and support resulting from access to informal networks that is decisive in professional success. The University of Stuttgart is planning to expand existing and successful mentoring programs for women in science and research to support even more female students in implementing their career strategies. The mentoring program provides support for highly qualified graduates, post graduates and post docs. An additional focus of the program is on qualifying women for leadership positions.

19. Mentoring Program "ProFiL BW"

The University of Stuttgart is planning to create a program to support excellence in scientific careers, following the example of the successful elite mentoring program "ProFiL" (http://www.profil-programm.de/, existing cooperation) of the three universities in Berlin. Future expansions of the program will include cooperation with other universities in Baden-Württemberg. The (female) participants of this program will receive extensive support in planning and furthering their careers, including training leadership and management skills required of a full professor. Prerequisite for joining this program is an excellent PhD thesis, a one or two-year post doc phase and an interview with the applicants.

20. "Ladies' Community"

Female students often feel isolated during their studies due to their low ratio in most engineering programs. Support programs like girls-only exercise courses are faced with a low acceptance as they are perceived as further reaffirming this outsider role. The lack of social infrastructure on-campus will grow even worse in the near future as first semester students are getting younger due to the shortened high school education. This development necessitates a pervasive community building among female students beyond the boundaries of the single study programs. The University of Stuttgart has created a work group to design a concept for realizing such a community. Some measures already planned include regular seminars with successful female entrepreneurs and researchers, regular social gatherings and the creation of a special web portal for the female community. The community to be created should ideally include all female students and alumni of the university.

21. Colloquium "Women in Leadership Positions"

Female students are often missing role models, women who have mastered the obstacles and challenges of a program and have reached a leading position in research or business, which results in low motivation and an increase in the drop-out rate. To counter this effect, the University of Stuttgart is planning to hold regular seminars where successful women from research and business share their experience and advice with female students. Future synergies with the "ladies' community" and the alumni program will support this measure.

22. Family Friendly University

It is necessary to provide a family and children friendly environment for young families or single students with children to attract more women to study or pursue a career at the university. The University of Stuttgart has already implemented a number of measures to this end. Among these are: child care for the children of students (Kinderbetreuung für Kinder von Studierenden der Universität Stuttgart STUPS e.V., emergency child care, semester break child care) and the Stuttgarter Forschungsferien, an attractive child care program for school kids, organized by the Konzept-e GmbH and five different Fraunhofer institutes.

Going beyond these measures, the University of Stuttgart is aiming at the creation of on-campus dorms with integrated child care for students with children and on-campus housing for young families of employees with comfortable access to nearby child care centres. By getting the students themselves to donate their time to help support the child care centres, we hope to decrease the financial burden and to help with community building among female students.

Additional important measures should address the specific needs created by the burden of raising children (part time studies, postponed exams due to a child falling ill, virtual courses). Researchers with children will profit mainly from dual career models, family friendly work processes, flexible time, and specific support for researchers during the first years of parenthood and the possibility of working at home. The University of Stuttgart is aiming to be the first university in Baden-Württemberg to gain the certificate as a "family friendly university" awarded by the audit council of the Hertie-Stiftung.

23. Re-Entry Program "SPIRIT returns"

The knowledge and skills of many qualified female researchers and engineers is lost to the market due to the massive obstacles when returning to a job after a prolonged absence due to pregnancy and child birth. The University of Stuttgart is searching funding from the ESF based on the BMBF-Program "Wiedereinstieg für Ingenieurinnen leicht gemacht". Engineers are given additional scientific training to re-qualify them for their re-entry into the job market.

24. Dual Career Service Program "DuCaSUS"

As accepting the appointment for a professorship usually involves moving to another city, the career chances of the partner are often a decisive factor in decision making process. A similar situation exists during the post-grad and post-doc studies. Dual Career Services can advance the career chances of researcher couples. Currently, the University of Stuttgart is expanding the dual career supporting policies already common in appointment negotiations to include post-grads and post-docs in the dual career service program "DuCaSUS". This program will involve the creation of a support network including regional businesses and public and private research companies to offer a larger basis of possible career opportunities for the partners outside the University of Stuttgart itself.

B. Comprehensive Measures for the whole Life-Cycle:

25. Chair for "Diversity Studies & Technology Management"

The Institute of Construction, Production and Vehicle Technology will create a new chair focusing on gender and diversity, based on the example of the "Chair for Gender Studies and Information Technology" at the TU Munich. The main aim is the strengthening and localization of the gender concept of the University of Stuttgart. The academic focus of the chair will be on interdisciplinary courses in the field of gender studies, in particular for the new program "Diversity Studies and Technology Management", as well as interdisciplinary courses offered to students of other programs at the University of Stuttgart.

26. Gender Components in New Appointments

The University of Stuttgart is trying to appoint scientist as professors whose research focus integrates an explicit gender and diversity focus. Examples for such new appointments would be "Diversity in Usability Studies", "Diversity in Design and Construction" (for a chair in civil engineering), "Gender Aspects in Biomedical Technology" etc.

27. Media Offensive "Fascination Technology"

One of the central challenges for engineering and science is the public image. While being accepted as important for technological advances and therefore economic growth, they are also perceived as dry and boring subjects. Technologically oriented programs often paint an unattractive image of technology as they focus on scientific theory and implementation but neglect to demonstrate social relevance. The result is a negative image of "soulless technology" as a simple means to an end, not as a field with its own aesthetic and fascination. This might be less of a problem for young men whose studies of a given field are often the result of a love affair with technology. In contrast, young women are more interested in social relevance than technology per se. The planned media offensive focuses on presenting mathematics, science and engineering as a vital and fascinating part of our modern culture. The methodology could be based on the experiences gathered in the popularization of mathematics at the MATHEON centre of research.

28. Media *Offensive "SPIRIT"*

A program can only be as good as its general acceptance and public interest. This is one major challenge for most current gender programs and measures to overcome. Gender programs have to incorporate and implement a pervasive PR strategy. This includes extensive online presentations aimed at addressing students living in more rural areas outside of Stuttgart itself.

29. eCRM "SPIRIT"

One major factor in the success of all measures described above is the continuous contact to the participating high school and university students as well as researchers. Our gender concept can only be successful if we manage to address these "customers" directly and tie them to the University of Stuttgart. To this end, an eCRM (electronic customer relationship management) will register and record all transactions between the University of Stuttgart and the participating students and researchers. As a result, they can be addressed directly and the life cycle process can be specifically tailored to each participant using intelligent agent systems (under the strictest observance of applying data privacy laws).

30. Brain Storming "SPIRIT"

The University of Stuttgart performs an annual brain storming on gender topics and diversity to define, select and implement further measures, with the participation of all interested institutes. The aim is a higher degree of flexibility and a stronger bound to the rest of the university.

C. Measures to Ensure Structural Implementation and Sustainability:

To ensure the implementation and sustainability of gender concepts the following catalogue of measures is implemented:

1) Pervasive Implementation throughout the University:

The single measures are placed within the jurisdiction of existing institutions (e.g. the office for equal opportunity), organizational centres (e.g. career or academic counseling), and the chairs of the institutes. Concrete tasks, their implementation and adaptation are fixed in target agreements with the president of the university. Additional measures focusing on strengthening the gender competency are the object of future appointment negotiations and target agreements. Internal projects reinforce the acceptance and broad basis for the concept.

a) Collaboration with Existing Equal Opportunity Programs:

Plans of equal opportunity in the academic [15] and non-academic fields define a catalogue of measures aimed at achieving equal opportunity for women, based on detailed analysis of the current state. The structural and organizational preconditions for these measures already exist.

b) Collaboration with the Female Professors Program:

The program to increase the ratio of female professors becomes a vital part of the gender concept. Individual professors assume the operative responsibility for particular measures. These measures have already been made to increase the public visibility of the program.

c) Strengthening the Scientific Gender Competency:

The chair of "gender in the engineering sciences" is a component for the success of the gender concept. It strengthens the scientific background and provides the expertise required in the evaluation and long term quality control. The chair provides new input for additional projects and necessary adaptations. The competency of the chair is enhanced by the support of the office for equal opportunity and related chairs.

2) Financing:

Financing for the SPIRIT program is based on a three-pillar model:

a) Budget:

The present shift to success-oriented funding allows for funding further or extended measures. Target agreements with the institutes will initiate additional measures. Measures focusing on students directly can also be funded from tuition fees.

b) Third Party Funding:

Third party funding is an important component in the development and test of new measures and concepts. The EU, the ESF and the National Ministry of Science and Education as well as industrial partners have been increasingly supportive of gender and diversity projects.

c) Endowment:

It is planned to found a SPIRIT-Foundation to raise additional funds for the gender concept of the University of Stuttgart. This foundation will approach the industrial partners already engaged in the Femtec project, regional SMEs, alumni of the university, and private donors that recognize the need to support gender in the regional economy. The financial goal is an endowment providing a total annual funding of € 500.000.

3) Responsibility – A priority for the President!

The implementation of a pervasive and coherent gender concept is seen as a vital challenge for the future success of a technologically oriented university. The coordination, further development and quality control of the program will be the responsibility of the president of the university, who will managethe program. Further developments will be coordinated with the commissioner for equal opportunity under the leadership of the president.

V. SUMMARY

The University of Stuttgart takes the female professor program of the state of Baden-Württemberg as an inducement to re-evaluate the currently used measures and proceedings in the area of equal opportunity and equal treatment. Where necessary these measures should be amended, enhanced and optimized. The major need for action does not affect the – numerous and successful – measures of the last years but does affect the gender culture at the University of Stuttgart. The measures should not only be carried by the equal opportunity department and the commissioners for equal opportunity. It is essential to further anchor the measures in research and teaching at the University of Stuttgart. At the same time patency and continuity have to be raised by developing a complete gender concept that views women and girls along a life-cycles model. It should group the different target groups and measures with regard to content and organization.

Furthermore, a natural science and technology-oriented university has to take special responsibility for the participation of women and girls in the evolution of technology in our society: Women are still underrepresented in almost all natural science and technological areas. This under representation has serious consequences – for women and for society. The demand for adjustment for women is not just a demand for equality of opportunity – in a country like Germany with few resources, economic success is tightly connected to advancements in technology. The future requirement for skilled personnel and managers in this field cannot be met by the current number of male graduates and the number of female graduates is nowhere close to enough to build the necessary specialized "‘mixed teams"’ which are expected to provide an important part of economic success.

The University of Stuttgart sees the sustainable implementation of gender-justice as an important challenge. The realization of a profound gender concept based on the observation of the complete life cycle with measures for different target groups – schoolgirls, female students and female scientists – will become an attractor for the University of Stuttgart to survive the fight for the best minds – on national and international levels. Within the scope of the overall process the university administration coordinates the existing activities and combines and expands on them. Numerous additional innovative measures are currently being prepared and will be sustained by a financial package containing budgeting, third-party funds, and endowments. The professorships within the female professor program serve as seeds for new impulses and will develop institutional and thus sustainable responsibility for important building blocks of the master plan. The gender mission statement is being created under the leadership of the president including a road map with measures for quality control and operative realization – henceforth gender is given top priority!

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Session 05A Area 1: Learning Systems Platforms and Architectures - Platforms and Learning Tools

Personalized Construction of Self-Evaluation Tests

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A Middleware for the Integration of Third-party Learning Tools in SOA-based Learning Management Systems

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Spanish University for Distance Education-UNED (Spain); University of Vigo (Spain)

Principles for the Design of a Remote Laboratory

Cagiltay, Nergiz

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Supporting Person-Centered Learning: Does the Choice of the Learning Management System Matter?

Comber, Oswald; Komlenov, Zivana; Motschnig, Renate

University of Vienna (Austria); University of Novi Sad (Serbia)

Evolutive Mechanism for E-Learning Platforms - A new approach for old methods

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Personalized Construction of Self-Evaluation Tests

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Abstract—**The European Higher Education Area, an agreement by 29 countries to unite and harmonise qualifications and Universities' rapprochement to the real demands of the labour market, will make a significant change in the traditional model of teaching tools to carry out more personalised monitoring of the student's work, leading to the possibility of continuous evaluation. The suitable use of Information and Communication Technologies (ICT) can make a contribution to improving the quality of teaching and learning. In this context, a self-evaluation platform is developed using the technology of Intelligent Agents. This system can be adaptable as it adjusts the various self-evaluation tests to the student's level of knowledge. Each student has a profile and, depending on this, timing and interaction is set by the agents.**

Keywords-component: e-learning, user profile, self-evaluation

I. INTRODUCTION

In June 1999, the Education Ministers from 29 European countries met in the Italian city of Bologna to approve the declaration for the convergence process towards the European Higher Education Area (EHEA). 2010 was set as a final deadline to finalize this process which will allow the unification of fundamental questions related to Higher Education studies in the European Union.

The basic aims set by the EHEA are the following:

- Create a system of university qualifications which are compatible in all Europe, divided into two cycles (graduate and postgraduate).
- Use the same university credit system in all European countries, based on the student's efforts.
- Promote student and lecturer mobility in Higher Education establishment.
- Design a new teaching model focused on the student who becomes the protagonist of his own learning.
- Establish a high quality evaluation system based on the student's continuous work.

To achieve these aims, one of the most significant changes in the EHEA is the new vision of the concept of learning. The traditional University system focused on teaching (by the lecturer) will become a system which is focused on the student's learning, through the use of more active teaching methodologies, more personalised monitoring of the student's work by the lecturer, and more involvement and student autonomy in the process of teaching and learning.

Another significant change of the EHEA concerns the process of evaluation. Traditional teaching methods measure the student's learning by using objective processes – both written and oral – which cannot evaluate the student's continuous effort and have no clearly formative objective. In this new educational scenario, the student's continuous evaluation and the absence of a teacher are the main axes of the formative process. The lecturer will assist and guide, designing various activities focused on acquiring the desired level of competence. One technique which has formative characteristics is a self-evaluation test. However, this type of assessment is not very useful as it cannot adapt to different student's profiles. Most software tools built to date which incorporate this type of assessment are not adapted to the student's individual characteristics nor do they allow the extraction of information on student behaviour when sitting the assessment.

II. SOFTWARE IN EDUCATION: BACKGROUND

We are familiar with software used in education which is a combination of tools used didactically to facilitate and improve the process of teaching and learning [1]. Numerous systems have been developed but the results obtained were not those hoped for. The reason is that most do not have clearly formative characteristics and allow any kind of programmed activity to be carried out by the lecturer, despite the fact that the student has not acquired the necessary knowledge to do so in optimum conditions. Moreover, they consider that one particular student's level of knowledge will be the same as the others in the group, regardless of work developed and personal circumstances.

The main aim of these applications should enable the development of initiative and the student's autonomous learning through different tools which will allow him to check his own work, take advantage of his potential capacity for learning and let him choose the tasks to do, how to do them and the level of depth. Moreover, they should facilitate constructive learning by tutoring the student's actions providing an explanation of the mistakes committed and offering opportune help and support. Finally, they should give the learner the mechanisms to be able to plan, regulate and evaluate his learning [2].

A brief historical summary of the application of Information Technology to teaching is showed next, starting with the most basic systems up to Intelligent Tutor Systems (ITS) devised in the '80s. We will later show some proposals of the current perspective supported in instructive and constructive didactic approaches, noting the contribution of Intelligent Educational Systems.

The first teaching systems under the name of *Computer Aided Instruction* (CAI) appeared between the '50s and start of the '70s. They provide information to the student in the form of three categories: (a) Lineal Programs, whereby all students receive the same knowledge and in the same order. The student's particular aptitudes are not taken into account. (b) Ramified Programs, which offer all students the same knowledge, but the order depends on their answers. These do not take into account the student's aptitude and the system acts in the same way when given the same answers. (c) Adaptive Systems whereby all students receive the knowledge adapted to their needs, both the difficulty of the problem and the detail with which they must answer. The problem with these systems is that they are not valid for all subjects and only accept a single answer to a problem when in fact there may well be several.

In the '80s, these type of systems evolved towards *Intelligent Tutor Systems* (ITS), which combine techniques of *Artificial Intelligence (*AI*)*, psychological models of the student and the expert, and theories of education. An ITS is an expert system in a subject which adapts the information to the student's needs. As the student's learning process occurs step by step, continuous updating will be necessary of the information stored in the ITS.

In the '90s, the application of AI techniques to the development of these systems led to *Intelligent Educational Systems (*IES). Unlike previous models, IES do not claim to substitute a classic system of teaching and learning, but are an alternative complement to improve the quality of teaching. Depending on the student's own learning, different types of IES are distinguished: (a) Intelligent Training Systems, based on an instructional focus in which the lecturer provides continuous student feedback. Its main disadvantage is the student's passive role which can lead to the loss of motivation. (b) Adaptive Hypermedia Systems (AHS), based on a constructive focus, whereby the student chooses the route of his learning from those programmed by the lecturer. As a consequence of this amount of freedom, the student can lose direction and not achieve his aims. Despite being opposing, both options are valid and necessary and can be complementary.

Currently, given the expansion and familiarisation of the Web, under the name of e-learning systems, there are various software solutions designed mainly for supporting un-staffed teaching and learning, although they serve as a support resource for traditional teaching i.e. platforms and software systems which permit communication and interaction between lecturers and students, access and sharing of contents, materials and resources, the application of co-operative strategies of learning etc., which support (to a large extent) the student's formative process. The main inconvenience is the lack of adaptation to the type of student involved in this interaction. Any e-learning system should adapt the form, quantity and difficulty of content to the student's qualification to motivate both his progress and how he reacts when faced with obstacles. Thus one must program systems which can build a dynamic student's profile which summarises his abilities and aptitudes as regards a concrete topic.

III. Creating a Student's profile

A student's profile could be set up by uniting a piece of data which reflects the student's competencies as regards concepts, procedures and aptitudes for a subject. Such information can be obtained easily from evaluating various objective assessments, such as examinations or tests and from the lecturer's subjective evaluations such as the learner's participation in the classroom or in tutorials. This information, clearly symbolical, could be used to personalize any type of student evaluation assessment, adapting it to the level of acquired knowledge and aptitude. This applies in the same form as the design of self-evaluation assessments.

A computational model of a student's profile which is dynamically adaptable and up-to-date can be set up by evaluating various self-evaluation tests and analysing how this is confronted and how to solve the problem [3]. As a general rule, traditional teaching is divided into various sessions or seminars with a teacher, and these are accompanied by complementary activities which aim to strengthen, consolidate and amplify the fundamental concepts presented in each session. Taking this into consideration, a student's profile would be made up of two components: (a) a particular component, which is obtained from the student's knowledge and aptitude for a concrete topic; and (b) a general component, which is the calculation of all the particular components of the student's profile.

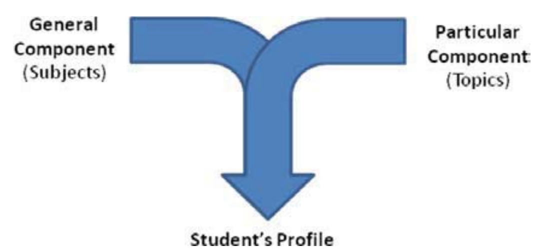

Figure 1. The components of the student's profile

The rationale behind considering this double component stems from the fact that the student may be very able in a concrete topic (as he has been successful in tests) whereas he lacks knowledge in other areas. Considering purely the general component of his profile, his knowledge would be low and consequently, further tests would not be difficult. Thus challenges would not increase and he could become demotivated. In the same way, if the successful result of a test raises the general component of his profile considerably, later tests would be more challenging even when the student has not shown a high level of competence. Thus, the general component of a student's profile measures his general competence in the subject and the particular component measures his level of knowledge and aptitude in each topic (Fig. 1). The former is updated when the student logout the system and its value is calculated as the average value of all profiles in each topic. The latter is updated after answering any test belonging to a given topic. The score of a test is a linguistic label representing the number of correct/incorrect questions answered and the student's behaviour whilst sitting the test. Table 1 shows how the student's current profile is updated by this score.

TABLE I. UPDATING STUDENT'S CURRENT PROFILE BY A TEST SCORE

Current profile	**Score of self-evaluation test**				
	Very high	**High**	**Medium**	**Low**	**Very Low**
High	High	High	High	Medium	Low
Medium	High	High	Medium	Low	Low
Low	High	Medium	Low	Low	Low

To obtain an initial student's profile, one can consider the mandatory realization of a number of non adapted tests. This initial profile would be constantly modified depending on results obtained in adapted test: correct/incorrect questions, consuming time to solve it, time to answer each question. This type of test would be set up automatically by selecting questions whose level of difficulty suits the actual student's profile: depending on his particular level of knowledge and errors committed when doing previous tests on the same topic. Once the test is corrected, the system shows the corresponding feedback and updates the student's profile (Fig. 2).

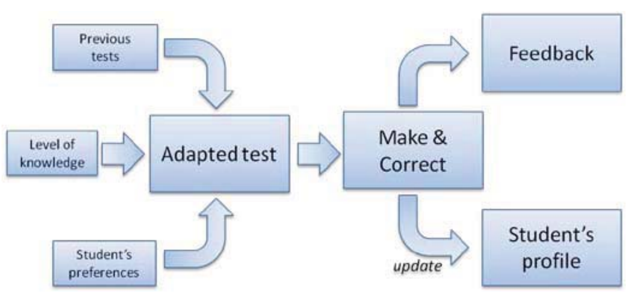

Figure 2. Three steps to personalize the construction of self-evaluation tests.

IV. COMPUTATIONAL MODEL OF THE SELF-EVALUATION PROCESS

As we have seen, in the new scenario created for the treaty of Bologna, evaluation is a process which continuously measures the student's effort. We have mentioned the use of self-evaluation assessments, adapted to the student's level qualification, as a means of evaluating acquired knowledge and help study. In this sense, we have developed a self-evaluation software tool, based on Intelligent Agents technology, which can automatically generate a test based on a personalised profile [3].

The multi-agent system developed uses a set of agents to manage the self-evaluation process, from the moment when the system is accessed, passing through the process of generating the test, to the moment when results are given. Fig. 3 shows the organisation of agents which carry out these tasks and which are described below:

- Interface Agents: interact directly with the User. These are classified as Student interface Agent and Generic Interface Agent.
- Intermediate Agents: carry out the tasks requested through the user interface. They are classified as Student Agent, Authentication Agent, Corrector Agent, Adaptor Agent, and Monitoring Agent.
- Information Agents: the Database Agent accesses the information stored in databases.

The main functionalities of the agents are detailed below:

- The *Interface Agent* allows the student's interaction with the tool. Two types can be distinguished: (a) *Generic Interface Agent,* for students who have not been authenticated, its aim is to negotiate access to the system for a User who is not authenticated, (b) Student *Interface Agent*, for authenticated users, its aim is to allow the student to do a self-evaluation test, inform him of the result, show the mistakes and give the feedback to improve his level.
- The *Student Agent* maintains the student's profile during the interaction with the system. Its aims are to inform and design the student's profile.
- The *Authentication Agent* controls a student's access to the tool and ensures he is identified until he has finished the interaction. It must check if the student is authenticated or not. When the *Authentication Agent* authorises access, a *Student Personal Agent* is created.
- The *Correction Agent* corrects self-evaluation tests. For this, it analyses and compares the information received from each of the student's answers, and the information stored in the database. It must correct and obtain the test result.
- The *Adaptor Agent* generates self-evaluation tests adapted to the student's profile. It endeavours to choose a host of questions and create the self-evaluation test.
- The *Monitoring Agent* supervises the student's activity when he does the self-evaluation test. One of its aims is to obtain the parameters of monitoring which depend on the difficulty and complexity of the topic of the test, i.e. the maximum time to do the test, the time for each question, etc. Another aim is to measure these parameters and give information on the student's behaviour whilst sitting the test.
- The *Database Agent* manages and centralises the access to information which is stored in the database. It must provide information on the User or on the test which will be created: questions available, configuration of the test and parameters to measure.

Each agent is assigned a set of sub-task and interacts with others agents to achieve his goals.

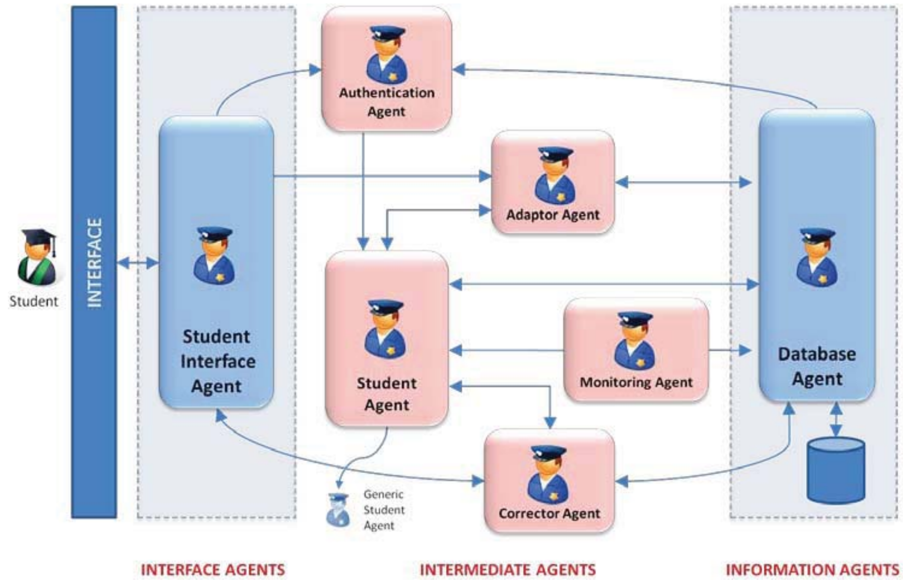

Figure 3. Organization of Multi-agent system.

V. IMPLEMENTATION OF THE SELF-EVALUATION TOOL

To implement the self-evaluation tool, a Web application has been developed whereby the agents' platform is situated. The global architecture of the system is composed of a Web client (a browser with which the student interacts), a Web server, and a database, as the multi-agent system is an extra component of this architecture as shown in Fig. 4. Through the Web interface, students interact transparently with the multi-agent system. The server collects information generated by interactions of the multi-agent system and database, from agents and from students. It processes and presents it in the form of dynamic Web pages.

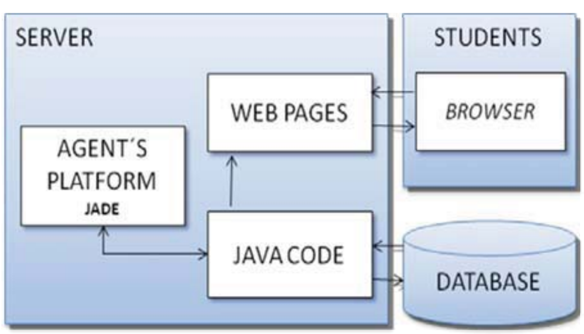

Figure 4. Global Architecture

Fig. 5 shows the interactions between agents to solve the request to obtain the result of a self-evaluation test, and how updating the particular component of student's profile:

- Ask for correction: the *Student Interface Agent* receives the request and sends it to the *Corrector Agent*.
- Ask for information on the questions: the *Corrector Agent* asks the *Database Agent* for the data necessary to correct the test, and when the test is corrected, the *Corrector Agent* sends the results to the *Database Agent* so that these are stored in the database.
- Carry out a correction: the *Corrector Agent* sends the test results to the *Student Agent,* charged with maintaining the particular component of student's profile belongs to a current topic. Also sends them to the *Interface Student Agent,* charged with showing the mistakes and giving the feedback to improve level of student.

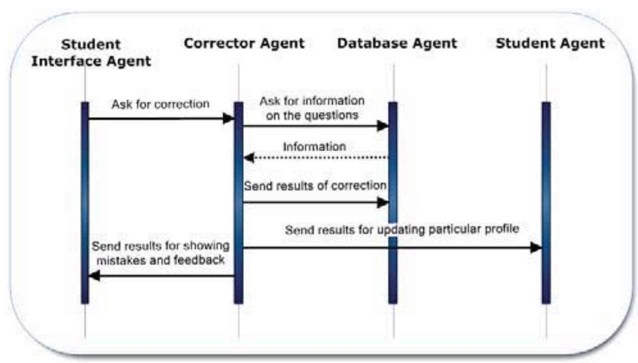

Figure 5. Interaction diagram to carry out a correction

Fig. 6 shows the interactions between agents when the student wishes to exit to the system and the general component of student's profile is updated:

- Request to exit: the *Student Interface Agent* receives the request to exit the tool and sends it to the *Student Agent*.
- Collect particular components of profile: the *Student Agent* ask the *Database Agent* for information about the particular profile in each topic.
- Update general profile: the *Student Agent* compute a new general profile from particular profiles and send it to the *Database Agent*.

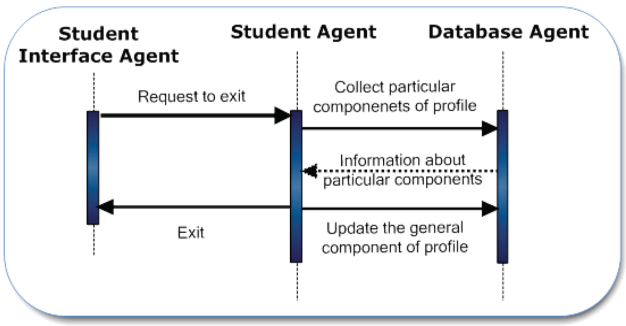

Figure 6. Interaction diagram to update the student's profile

The implementation of this architecture implies the integration of different technologies. Firstly, the multi-agent system is modelled by the IDK, tool of INGENIAS [4], an agent methodology which extends MESSAGE and establishes how a Multi-agent System has to be modelled and integrated with the "best practices" of engineering. The tool uses the Agents' platform JADE compliant with the FIPA standard.

Secondly, the Web application is developed in J2EE. For this, Apache technology known as STRUTS is used, following the Model-View-Controller pattern of architecture.

Finally, information on the students and the process of self-evaluation is stored and managed in a database implemented with MySQL.

VI. Conclusions

The EHEA proposes a teaching model which is student focused, as the evaluation will undergo a substantial change as will the student's level of knowledge, effort and continuous work. To carry out the changes considered by the EHEA, one must provide all the necessary help, not only to the students, but also to the lecturer.

Self-evaluation is a process which starts with an assessment in the form of a test and ends with information on errors committed. This type of assessment is beneficial both for the student and lecturer. For the student, a test result is an objective evaluation of the level of knowledge, understanding, mastery and progress reached in the subject, which allows him to direct his learning. In turn, the lecturer can gather significant information on the degree of satisfaction of the initially set aims, which will evidently depend on teaching strategies and resources.

To resolve some of these needs, a self-evaluation tool has been developed which allows the student to evaluate his learning process, helping him to check and consolidate his acquired knowledge and motivating him in his search for further knowledge. This tool can be adapted for each student, which satisfies a series of objectives. Firstly, it gives the student a flexible and dynamic way to evaluate his level of knowledge and know where he must improve. Secondly, it involves and motivates the student in his own process of learning. Thirdly, and lastly, it facilitates the continuous monitoring and evaluation of students by the lecturer, thus alerting him to competencies which will be more difficult to acquire.

The tool uses a Multi-agent System to build a student's profile based on the results of the self-evaluation test. Moreover, it records student interaction with the tool, generate adapted tests, and choose questions (and level of difficulty) which will be part of the test.

Therefore, by using this tool, the student will be able to control, verify and promote learning through the self-evaluation tests adapted to his profile and from the information of feedback generated by the agents once the test is corrected.

Acknowledgment

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A Middleware for the Integration of Third-party Learning Tools in SOA-based Learning Management Systems

Supporting Instance Management and Data Transfer

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Abstract— **The widespread adoption of broadband Internet connections and the need of institutions such as universities or enterprises to provide their staff with continuous education have led to a fast adoption of Learning Management Systems. These systems typically provide a centralized environment where students can communicate, carry out experiments, etc. However, the rapid growth of these platforms together with the unlimited need for learning tools, mainly in engineering education contexts (e.g. simulators, communication tools), are hindering their development. The natural alternative is to decouple these tools from the Learning Management Systems themselves, taking advantage of the *Software as a Service* distribution model. To perform such a decoupling a middleware is required to allow the integration and use of an external tool by the Learning Management System. In this paper a proposal for such middleware is described, with a special focus on the part devoted to manage instances and the transfer of data.**

Keywords- Data-transfer interface; Hard integration; Instance Interface; Learning Management Systems; Middleware; Software as a Service.

I. Introduction

Engineering education is experiencing great changes during the last years. Many of these changes have been promoted by the adoption of new technologies, broadly Web-based applications. Learning Management Systems (LMSs) are playing a key role in this scenario. Some of the best-known examples are Moodle [1], Blackboard [2] and .LRN [3]. These systems typically facilitate the control of educational activities, providing a centralized environment to organize and provide information, to support the communication between teachers and students, to enable the interchange of documents, to answer online questionnaires, etc. Nevertheless these LMSs are too generic. The "one size doesn't fit all" problem is very notorious here, since their functionalities are generally designed for the support of a general educational approach based on the delivery of contents. Nevertheless, many engineering subjects require not just the delivery of contents, but also the performance of experiments, practical developments and collaborative works among students. During the last years these activities have been supported in several ways by technology-based solutions developed outside of the LMSs: simulators, remote labs, agent-based environments, games, immersive environments, etc. As a result, a plethora of tools and services is currently required for the support of engineering education e-learning courses, but in general they are not available in LMSs.

The previous problems have been identified as LMSs' tailorability and extensibility deficiencies that need to solved. Up to date, some solutions have been proposed, but with limited success. For example, Moodle and Blackboard have capabilities to extend their own functionalities: the so-called "extensions" [4]. However, in these systems integration of external tools is considered only a supplement. As a result, it is possible to include a new tool in Moodle or Blackboard, but the integrated tools do not work in coordination with the core LMS. On the one hand, LMSs lack any means to monitor and control the way users work with tools. This is the case, for example, when we want to track students' activities. On the other hand, LMSs are not able to control the interaction of the users with the external tools.

The tailorability and extensibility deficiencies found in existing LMSs, together with the essential need of extensions, have led us to the conception of a middleware to enhance and facilitate the integration between LMSs and third-party tools. This middleware is based on a *Software as a Service* (SaaS) distribution model that allows the LMS to use third-party tools exposed as Web Services. In this paper we give an overview of the different communication protocols, components and software stacks involved. A comprehensible description is out of the scope of this article, and therefore we put the focus on two key parts of the middleware: the Instance Interface (those elements to create and manage the instances of a third-party tool), and the Data-Transfer Interface (those devoted to

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transfer data elements between the LMS and the tool). Their development has been based on the study of existing solutions and the application of a rigorous analysis of requirements.

This paper is organized as follows. Section 2 analyzes different ways in which LMSs can be extended according to the level of functionality achieved, and puts the data-transfer middleware in this context. Section 3 poses a typical scenario where the need of creating and configuring instances and transferring data between a LMS and a tool is clear. Next, Section 4 gives a brief description on the middleware and the way it has been structured to accomplish integration of third-party tools, and Sections 5 and 6 focus specifically on the Instance Interface and the Data-Transfer Interface. Section 7 provides a proof of concept, and Section 8 ends up with some conclusions.

II. Integration of Third-Party Tools

The basic problem of this research has been how to develop an LMS whose functionality can be extended at a minimum cost. In addition, the new functionality has to be appropriately integrated with the previous one of the LMS. This problem can be considered in a broader context, as the general problem of extending a Web application.

At this point we have considered two different alternatives to integrate third-party tools in a Learning Management System, which are also considered in [5]:

- Soft integration of third-party tools. The LMS functionality can be extended through a hyperlink to an (external) third-party component. Once the user clicks on it, the graphical user interface of the tool is displayed. From this point, users are operating a system that the LMS cannot control by any means. Therefore, a new functionality is included but it does not work in coordination with the core LMS, resulting in a very “soft” integration.
- Hard integration of third-party tools. It includes the soft integration, but providing the LMS with comprehensible control over the integrated tools. We describe in the next paragraphs our proposal for such a comprehensible control.

In soft integration a third-party application can be “inserted” in the page of the LMS, providing its users with a unified environment to carry out their tasks. However, the only part of the application that can be controlled by the LMS is a link to the tool. The LMS does not have any means to supervise and alter the behaviour experienced by its users on the application. This functionality can be enough in some cases, but not always. Hard integration, on the other hand, allows the LMS not only to link the application, but also to supervise and alter the behaviour of the tool as required.

As discussed in [6], the control of the operation of the tool to achieve hard integration involves the following issues:

1. Creating a working account (i.e. an instance) for each user at the tool. For example, in a “Hydrodynamics” course an instance can be created for a student at a fluids simulator.
2. Transferring from the LMS to the tool all those data that the user may need in order to carry out his/her tasks. In the case of a fluids simulator, the LMS may send the boundary conditions required for the hydrodynamics problem.
3. Establishing some access permissions over these data and the tool functionality. In our example, the student may be assigned execution permissions over the part of the application responsible for launching the simulation.
4. Subscribing to events result of the manipulation of the tool. For example, the LMS may be interested in knowing when the student launches a simulation, and hence it has to subscribe to the corresponding event type.
5. Authorising the user to access the instance. In our example, the student may not have a working account at the fluids simulator, in whose case the LMS has to grant him/her access as guest user. Otherwise, if the student is not involved in the subject he/she should not be granted access.
6. Altering the behaviour of the tool according to the information provided by the events triggered. For example, if the result of the fluids simulation is correct the LMS may order the simulator to give a verbatim explanation of the physical laws involved in the problem.

Figure 1 summarizes the difference between hard and soft integration in terms of the six aspects mentioned above.

III. An API for the Integration of Tools

The highest level of integration can be provided by the architecture depicted in Figure 2. The picture corresponds to a refinement of the TCP/IP protocol stack. Unlike the typical TCP/IP stack, the Application layer is further decomposed into three additional layers:

- **High-level entities**. The LMS and the third-party tool. They provide the bulk of the learning functionalities, but employ the integration managers to interact and complement each other.
- **Integration managers**. A set of classes and interfaces used by both high-level entities that enable to control and supervise the behaviour of the third-party tool by the LMS. In other words, these integration managers carry out tasks that enable to achieve hard integration. Each integration manager deals with a different task.
- **Integration protocols**. A set of protocols that allow the integration managers at the LMS and the tool to communicate.

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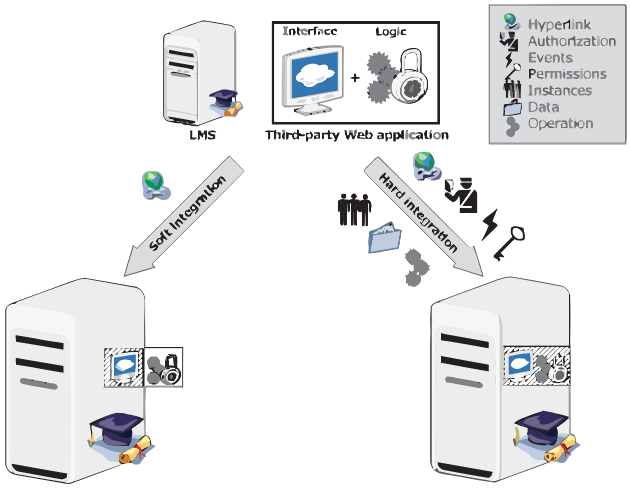

Figure 1. Difference between hard integration and soft integration.

As in the standard TCP/IP stack, each layer perceives a direct communication with an analogous layer at the remote host. Therefore, integration protocols communicate with analogous integration protocols, integration managers communicate with analogous integration managers, and high-level entities communicate with high-level entities, see Figure 2.

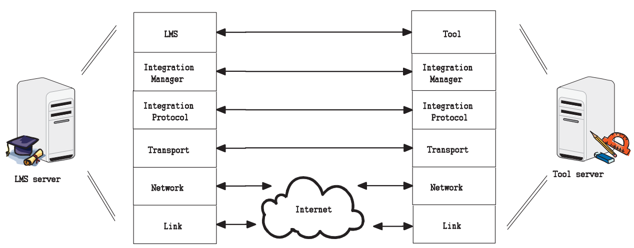

Figure 2. Hard integration architecture.

The conceptual layer diagram of Figure 2 is complemented by a class diagram representing the classes, components and interfaces that build up the layers of both the LMS and the Tool. Figure 3 provides such diagram just for the case of LMS. The diagram of the Tool is symmetrical due to the abovementioned property of the TCP/IP protocol stack of direct communication between layers.

In this diagram the high-level entity is represented as a UML component without any further class decomposition. The reason is that a high-level entity is a complex system, involving many classes and packages whose relationships are not relevant for our purposes.

Beginning with the diagram of Figure 3, the LMS invokes the methods of the integration managers to alter the behaviour of the tool (e.g. a method for granting write permissions over a file, for subscribing to a particular event). Each integration manager deals with a different aspect of hard integration, up to the six different aspects enumerated in Section 3.2. The LMS does not have to worry about the code structure of the integration managers but only about the methods they provide and the functionality of each of them. Therefore, each integration manager realizes an interface, which is exposed to the LMS.

The integration managers of the LMS use the integration protocols to communicate with the tool. The integration protocols, both those at the LMS or at the tool, carry out the effective exchange of messages, dealing with the logic of the messages sent between both entities (sequencing, detection of invalid messages, etc.).

When the message has been delivered to the integration protocol of the tool it is passed to the corresponding integration manager, which alters the behaviour of the tool.

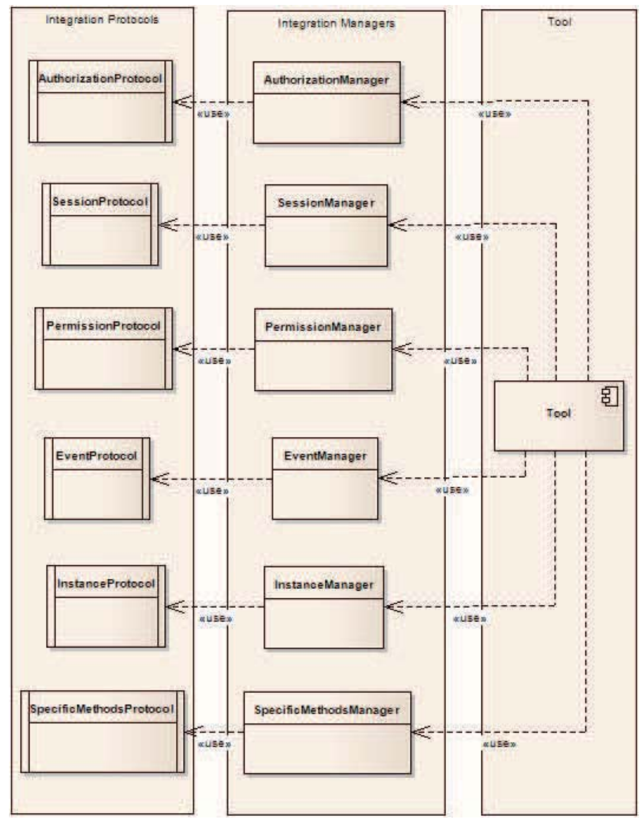

Figure 3. UML class diagram of the LMS.

In this article we will describe only the Instance Manager-Protocol and the Data-Transfer Manager-Protocol. Taking this framework as a starting point, the only missing points are the following:

- Firstly, an enumeration of the methods supported by the Instance Manager and the Data-Transfer Manager.
- Secondly, a description of the way the Instance Protocol and the Data-Transfer Protocol work.

In order to specify the functionalities of both pairs Manager-Protocols (or simply "Interfaces") we will firstly describe a typical use case in Section IV involving the creation and management of instances in a remote tool, and the transfer of data between a LMS and the tool. This use case will help us to develop the abovementioned logic in Sections V and VI. The descriptions carried out in Sections IV, V and VI follow a constructive approach, i.e. they represent the same creation process taken by the authors when developing the full middleware.

IV. A Typical Scenario

For our purposes (defining the Instance Interface and the Data-Transfer Interface) we will consider a LMS hosted and managed by the University A. This LMS offers its students the possibility to use a collaborative tool hosted and maintained by the University B.

Students of a certain course in a Telecommunications Engineering degree use the University A's LMS. At a certain part of the course, students are expected to work in groups to accomplish a task. The tool at University B provides the desired functionalities. Therefore, the LMS creates one instance of the tool per working group. The work of one group should not interfere with another group's (e.g. a group should not cheat trying to copy another group's work). In this way, when the members of the group get access to the tool they join their particular instance where they find a copy of the wording of their assignment along with appropriate documentation.

At a certain point of the schedule the teacher wants to qualify the pieces of work created by each group. At this time, the access to the instances needs to be blocked. When the teacher finishes the qualification instances are unlocked again to enable students continue working. This unlock may be followed by the transfer of the wordings of new assignments.

During all the process it is feasible that some students may have some tasks validated by previous activities. In this case they do not need to perform the assignments and therefore their membership to their respective groups should be revoked. Similarly, some new students may be assigned to some existing group by some reason.

Suddenly, some unexpected behaviour is experienced at the tool provided by the University B (e.g. server crashes). In view of this fact the LMS requests a full backup of all the data generated by the groups. If University C provides a tool with similar functionalities to University B's the LMS creates new instances in University C's tool for each group and restores the backup copies in them.

In sections V and VI we use this scenario to explain the requirements we have identified for the Instance and Data-Transfer Interfaces. We adhere to a strict software engineering approach, firstly identifying the requirements of a solution, then analyzing existing technologies against these requirements, and finally coming up with a proposal that overcomes the identified limitations.

V. The Instance Interface

The first of the interfaces that will be described is the Instance Interface. This Interface is devoted to the control and management of the instances of a tool. We understand by *instance of a tool* a working environment along with a graphical user interface, several files to manipulate, and a set of users allowed to access it.

A. Requirements

On the basis of the use cases included in the scenario described in Section IV we can enumerate the following requirements for a data-transfer solution:

- **Interoperability**: the LMS should interoperate with a Web tool even if they are in different network domains. This is necessary as in the general case the Web tool and the LMS are located at different network domains.
- **User-oriented instances**: as pointed in Section IV, it should be possible to add specific users to specific instances of the tool. Particularly, depending on the kind of tool one instance could be assigned one or many users.
- **Disjoint instances**: the membership of one instance should not affect either the membership or the state of other instances.
- **Dynamic reconfiguration**: it should be possible to remove participants from an instance or add new ones during runtime.
- **LMS-controlled membership**: it is the LMS which decides which user is assigned to each instance of the tool. In Section IV it is the LMS which creates the working groups.
- **LMS-controlled instances**: the LMS should be able to create, delete, suspend temporarily and resume instance depending on the requirements of the course. In Section IV the LMS suspends the instances during the teacher's evaluation.

B. Related Works

Previous to the development of an interface we perform a study of the state of the art. Unlike other interfaces such as the Data-Transfer Interface in Section VI or the Authorization Interface [7], the study of the state of the art in the field of instance management did not bring out significant results. There are not systematic approaches to control and manage instances, which in part is understandable due to the vast diversity of tools and requirements involved.

Given this heterogeneity we decided to concrete our research and investigate the state of the art of the most common learning tools [8]. This research has been fruitless in many cases, but in the fields of chats and conferences we came across several specifications to define how to create instances and manage them once created.

RFC2811 [9] addresses the creation and control of chat rooms or "channels" (i.e. concrete instances of the chat tool). In its simpler version, new channels are created whenever its first user joins it. This user is assigned the role of "channel founder" and has unlimited privileges over the channel. Since the channel is created other users are free to join it unless the founder explicitly puts them in a black list. Other parameters that can be set by the founder include silencing the room, setting a welcome message, or establishing a user limit for the

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channel. When all users have left, the channel is finally deleted.

RFC4353 [10], on its turn, specifies how to use the SIP protocol in order to initialize, modify and terminate media sessions between multiple participants or “conferences”. The RFC regards a specific conference as an instance of a multi-party conversation. The document addresses common instance operations (creating and destroying an instance, and adding, removing and listing participants) and specific conferencing operations (adding and removing media, and recording a conversation).

Table I summarizes the behaviour of these two specifications against our requirements.

TABLE I. COMPARATIVE ANALYSIS OF RFC2811 AND RFC4353.

	RFC2811	RFC4353
Req. 1	YES	YES
Req. 2	YES	YES
Req. 3	YES	YES
Req. 4	YES	YES
Req. 5	NO	NO
Req. 6	NO	NO

We see that these RFCs have been written to describe services that, although they behave well against our requirements, they have not been thought to be operated by a third-party system but directly by (one of) its users. Therefore, our Instance Manager offers similar functionalities to these RFC, but providing the LMS with full control of the creation, deletion and state of the instances. Eventually, this control could be transferred by the LMS to the users.

C. *The Instance Manager*

As described in Section III, the approach we have followed is the decomposition into a Instance Manager providing a known interface, and a Instance Protocol responsible for the actual transfer of data (see Figures 2 and 3). Both the Manager and the Protocol have to be implemented at both the LMS and the tools. Table II summarizes the methods and input and output parameters of the Instance Manager.

TABLE II. METHODS OF THE INSTANCE MANAGER.

Method	Input parameter	Output parameter
createInstance	name	URI
suspendInstance	URI	result
resumeInstance	URI	result
addUser	URI, userID	result
removeUser	URI, userID	result
deleteInstance	URI	result

Instances are uniquely identified by its URI (Unified Resource Identifier). All operations receive the URI of the instance as an input parameter (except the method for creating an instance, which returns the URI of the new one). The field *result* contains a verbatim message containing the success or not of the operation (e.g. “OK”, “Error - Instance not found”). Finally, each LMS is responsible for assigning its users a unique *userID* to avoid colliding usernames at the tool.

D. *The Instance Protocol*

The specifications described in Section V-B describe complex and very specific protocols to manage instances from an external entity, which do not adapt to our scenario. Therefore, a light Instance Protocol has been specifically designed to work with the Instance Manager.

The Instance Protocol is based on the exchange of plaintext HTTP messages with specific headers. All the message exchanges take place exclusively between the LMS and the tool (i.e. the final user of the tool does not take part in them). HTTP is specially suited for the design of a client-server interface such as the Instance Interface, as it offers the capability to send parameters in the header of the messages.

The format of the headers follows a simple structure. Each parameter goes in a different extension header. For example, should the parameter URI be sent, the corresponding header would be something like *URI: www.mylearningtool.net/specificinstanceuri*. Additionally, there are two more headers. On the one hand, the *InstanceMethod* header specifies the method of the Instance Manager that is invoked by the LMS. On the other hand, the *RequestID* header identifies the request from any other request from this or any other LMS. This is useful for the LMS to match the incoming response with a previous request. Figure 4 depicts a sample message of the Instance Protocol.

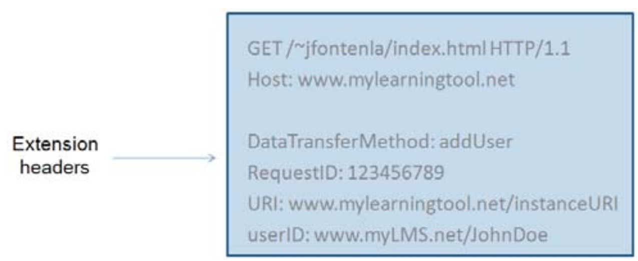

Figure 4. Sample message of the Instance Protocol.

VI. THE DATA-TRANSFER INTERFACE

In this section we describe the Data-Transfer Interface. As described in Section III, the approach we have followed is the decomposition into a Data-Transfer Manager providing a known interface, and a Data-Transfer Protocol responsible for the actual transfer of data (see Figures 2 and 3). Both the Manager and the Protocol have to be implemented at both the LMS and the tools, in order to allow the virtual direct communication among layers described in the TCP/IP protocol stack. It has been our intention to build a simple and lightweight solution that could work in any kind of learning environments where two entities need to transfer data.

The structure of this section is analogous to that of Section V. Starting with an analysis of the requirements, we list some related works and study their behaviour against our requirements. Next, we get into some detail of a Data-Transfer Manager and a Data-Transfer Protocol solving the previous limitations.

A. Requirements

As with the analysis of requirements carried out for the Instance Interface in Section V, On the basis of the use cases included in the scenario described in Section IV we can enumerate the following requirements for a data-transfer solution:

1. **Interoperability**: the LMS must be able to interoperate with a Web tool even if they are in different network domains.
2. **Bidirectionality**: the solution must enable to transfer data either from the LMS to the tool, or from the tool to the LMS. Moreover, the communication can be started by any of these entities. For instance, in the example of Section IV the tool could fetch from the LMS an avatar for each student.
3. **Granularity and bulkability**: the solution should accept the transfer of single data elements (Granularity) as well as the transfer of multiple data elements in a single message (Bulkability). In the use case of Section IV, for example, transfers involve both single data elements (the wordings of the assignments) and full backup copy.
4. **Scheduled and on-demand transfers**: the transfer of data can be made either on demand, or in a scheduled fashion. In the latter case, it should be possible to specify at least the time of the transfer, and which data elements are going to be sent. For instance, in the scenario of Section IV the LMS could request backup copies from the tool of University B every hour.
5. **Bandwidth efficiency**: the solution should not be bandwidth intensive (e.g. in the case of frequent bulk copies). This includes the sending of incremental backups, including just those elements that changed since the previous copy.
6. **Transparency**: the user should not be aware of the data-transfer process that is taking place while he/she is using the tool.
7. **Integrity**: in the general case, the data being transferred is not fault-tolerant. Hence, the solution should provide some mechanisms to check the consistency of the data.
8. **Confidentiality**: the solution should provide mechanisms to treat the data as confidential when necessary.

B. Related Works

During the course of our work we studied several standards and technological products devoted to the transfer of data between two entities. Some of these products have relationship with the e-learning field, while some others are for general purpose. Aware that this is a very wide category, we chose the following three representative technologies for study: SCORM RTE, IMS SSP and W3C's Storage interface.

ADL Shareable Content Object Reference Model [11] (henceforth SCORM) is an effort to provide a set of specifications, guidelines and standards to meet the requirements for the Web-based delivery of reusable learning contents. One of the results of this effort is the SCORM Runtime Environment [12] (henceforth SCORM RTE), which details the requirements for launching content objects (henceforth SCOs) and establishing communication between LMSs and SCOs. The RTE is a middleware that is downloaded to the learner's Web browser along with the SCO itself. Whenever a SCO wants to begin a data transfer with the LMS invokes the *getValue* or *setValue* methods of the RTE. All the transfers are initiated by the SCO.

There are two main deficiencies in SCORM RTE that avoided us from choosing it as our data-transfer solution. Firstly, it provides a very limited set of methods, as it only allows the transfer of single data elements and not full backups. Secondly, it has been designed with a very concrete and simplistic scenario in mind (namely, a SCO making requests to a LMS following a client-server approach) which is slightly different from ours. We are considering tools in general and not SCOs uniquely.

IMS Shareable State Persistence [13] (henceforth IMS SSP) has been posed as an extension of SCORM to support the storage and retrieval of information from shared dataspaces called "buckets". The main goal of IMS-SSP has been to provide SCORM's SCOs the ability to share information among them which, according to the IMS, would allow to make more reusable content objects.

On addition to the methods *getValue* and *setValue* of SCORM RTE, IMS SSP considers the methods *appendData*, *getData* and *setData* that work over buckets. Unlike the methods of SCORM, these three methods allow not only to transfer single data elements but also collections of them with a single call. Nonetheless the operation of IMS SSP is similar to SCORM RTE's: it has been designed for scenarios where SCOs makes requests to an LMS by means of a runtime, and the LMS consequently replies to the request. There is no kind of bidirectionality between the entities involved. Other requirements of Section VI-A such as Bandwidth efficiency, Integrity or Confidentiality are neither considered.

Finally, W3C Storage [14] is a mechanism designed for storing user's data in general-purpose Web applications due to the W3C Consortium, allowing persistent storage lasting the current browser session. Storage has been developed as an interface to access a standardised set of methods in the Web application. These methods include *getItem*, *setItem*, *removeItem* and *clear* to operate over data elements represented as key-value pairs (both keys and values are strings). The invocation of these methods is carried out by some JavaScript code running in the browser. Despite Storage is designed for a general-purpose scenario involving a Web application and a browser, its working principles remain the same with regards to SCORM RTE and SSP. The specification involves a client-server architecture where the browser makes requests to the Web application, and the latter performs some operations over the stored data and replies to the browser. On top of that, the set of methods work over specific data elements and do not allow any kind of planned transfers or incrementality. All these issues are a consequence of the fact that Storage is a quite simplistic solution for our needs, and therefore exhibits a poor behaviour against our requirements.

Table III summarizes the analysis of the three technologies considered in this section against our requirements.

TABLE III. COMPARATIVE ANALYSIS OF SCORM RTE, IMS-SSP AND W3C STORAGE.

	SCORM RTE	IMS SSP	W3C Storage
Req. 1	YES	YES	YES
Req. 2	NO	NO	NO
Req. 3	NO	NO	NO
Req. 4	NO	NO	NO
Req. 5	NO	YES	NO
Req. 6	YES	YES	YES
Req. 7	YES	YES	YES
Req. 8	NO	NO	NO

C. The Data-Transfer Manager

The underlying Data-Transfer Protocol is wrapped by the Data-Transfer Manager, which provides a standardised set of methods. Five methods, summarized in Table IV, have been considered to read the value of a data element (*getDataElement*), to overwrite it (*setDataElement*), to get an on-demand backup copy of the data of the instance (*getBackup*), to restore it (*restoreBackup*), and to schedule the transfer of future copies (*scheduleBackup*). These five methods can be divided into two groups: those that can be invoked by either the LMS or the tool (*getDataElement* and *setDataElement*), and those that can only be invoked by the LMS (*getBackup*, *restoreBackup*, *scheduleBackup*). An example of the first kind of methods takes place when the tool requests the name of the learner to the LMS using *getDataElement*, whilst an example of the latter could be an LMS requesting a backup copy of the data hosted at a tool by the use of *getBackup*, and transferring it to another tool using *restoreBackup*.

Table IV shows the methods along with their input and output parameters. All of them have an *id* input parameter, which refers to an identifier of the data involved (whether a single data element or a full backup). The parameter *data* contains the value of the data element or the backup being transferred, and has the same meaning whether considered as an input or output parameter. The parameter *result* contains a verbatim error code, if any (e.g. "The requested data element has not been initialized"). Finally the parameters *incremental*, *time* and *period* are specific for the request and scheduling of backup copies. The parameter *incremental* contains "false" or "true" if the backup is considered standalone or incremental. The former includes all the data at the tool, while the latter only contain those files that have changed since the last backup. This "incrementality" boosts the performance of a backup transfer, which is typically bandwidth-intensive. On its turn, the parameters *time* and *period* are devoted to schedule the periodical transfer of copies from a predefined point in time (e.g. the transfer of copies every 10 minutes from 9 pm).

TABLE IV. METHODS OF THE DATA-TRANSFER MANAGER.

Method	Input parameter	Output parameter
getDataElement	id	data
setDataElement	id, data	result
getBackup	id, incremental	data
restoreBackup	id, data	result
scheduleBackup	id, incremental, time, period	result

D. The Data-Transfer Protocol

A simple Data-Transfer Protocol has been specifically designed to work with the Data-Transfer Manager. The reason is that none of the technologies described in Section VI-B satisfies our needs to request, pack, transfer and restore data, and therefore a light ad-hoc Data-Transfer Protocol has been developed.

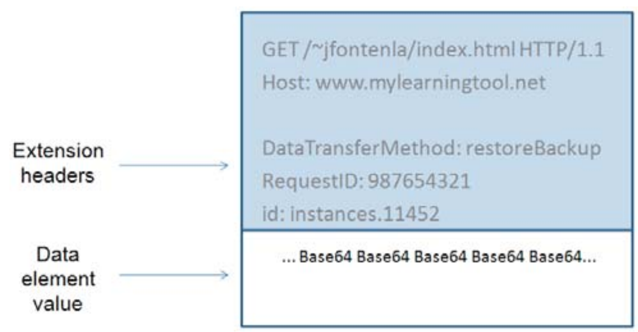

Figure 5. Sample message of the Data-Transfer Protocol.

As the Instance Protocol, the Data-Transfer Protocol has been designed as an extension of the HTTP protocol with special header extensions. Again, HTTP is specially suited for the design of a Data-Transfer Protocol, as it offers not only the capability to send parameters in the header of the messages (with the same format of the Instance Protocol), but also a payload to transfer binary data. On top of that, HTTP provides integrity as it works on top of TCP. In case that confidentiality

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(e.g. when a learning tools wants to transfer the marks of a questionnaire to the LMS, at the transfer of a personal email account linked to an instant messaging application) or authenticity (e.g. to verify that the LMS managing the session data is the same that created the user account) were required, the Data-Transfer Protocol could use HTTPS instead.

Data are encoded using the BASE64 schema [15], and sent in the payload of the HTTP message. Full backup copies are packed as zip files prior to their transfer by means of the Data-Transfer Protocol. The use of this format is not as unusual as it may seem, as it is also the format used by Moodle to pack and transfer educational contents [16]. Should any problem occurred during the processing of the request, an error code would be returned for the Data-Transfer Manager, along with the habitual HTTP error code for the Data-Transfer Protocol. Figure 5 depicts a sample message of the Data-Transfer Protocol.

VII. Proof of Concept

In order to demonstrate the feasibility of the approach, a prototype consisting of a LMS and a learning Web tool has been designed. Acting as LMS we deployed an instance of Moodle (henceforth, "the LMS"). The choice of Moodle responds to its important presence in online universities, as well as to its opensource-ness. On the other hand, we deployed another instance of Moodle just to use one of its tools (a forum). The capabilities of the second instance of Moodle (henceforth, "the forum") to work as a full Learning Management System are not used, but only its forum. Whenever a user of the first instance of Moodle wants to use a forum, the one of the second instance is used instead. The forum of the first Moodle is "bypassed".

A full implementation of the six parts of the middleware described in Section III has not been made yet. Instead, we just implemented the Instance Interface, Data-Transfer Interface and Authorization Interface in both instances of Moodle.

A simple test, summarized in Figure 6, has been made. Firstly, the LMS used the Instance Manager to create a new instance of the forum (i.e. a new conversation thread) named "Waves". When the instance has been created, users must be added. In our case we added a student whose LMS user account had been previously created manually. This action does not grant instant access to the instance, but instead tells the forum that the instance will be visible to the user when he/she joins.

The next action carried out by the LMS was to post a welcome message giving some explanations about the wave equation. In terms of the middleware, this implied using the method *setDataElement* of the Data-Transfer Interface. During this proof of concept we tried to avoid the use of a complex agreed vocabulary in order to describe every data element hosted at the forum. Instead, we only used a data element called *newMessage*, but the Data-Transfer Interface is flexible enough to support any kind of vocabulary as long as it had been previously agreed by both parts.

Finally, when the user accessed the forum application (by means of the Authorization Interface, whose description can be found in [7]) found the post of the LMS as if it had been posted by any other user.

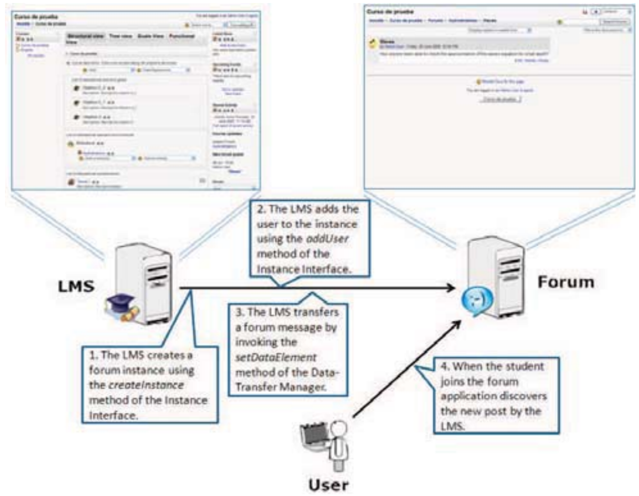

Figure 6. Proof of concept.

VIII. Conclusions

Current LMSs are playing an important role in providing engineering education. However, their possibilities are limited due a clear "one size doesn't fit all" problem. These limitations have been the starting point of our research. The work described in this paper tries to tackle these issues with tailorability and extensibility in mind by the use of the SaaS software distribution model.

The architecture described in this work is devoted to take advantage of the SaaS model while at the same supporting the concept of hard integration. At different with current solutions that only enable a soft integration of third-party tools, our architecture allows a harder level of integration. As a result, the LMS can extend its functionality, and can do it in a controlled way.

Our proposal not only implies the design of a new kind of e-learning system, but also an entirely new business model where the development of LMSs and educational tools follow separate (but complementary) ways. In the final term this business model implies more opportunities to bring students a better and more applied education.

One aspect of the Data-Transfer Interface we deliberately omitted is the use of some sort ontologies or agreed vocabularies in order to uniquely identify each resource hosted at the remote tool. Nonetheless, as pointed in Section VII the Data-Transfer Interface provides enough flexibility to support any kind of shared (semantic) knowledge. In fact, when we began to work on the interface we assumed as a starting point that there is already some kind of shared vocabulary, but no effective data-transfer mechanism between LMS and tools.

Currently we are working on the middleware to give full support to the other aspects of hard integration, apart from the

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two interfaces described here and the Authorization Interface described in [7]. Nonetheless, the six parts we have considered are completely independent from each other, and they can be used in a standalone way if desired. The source code of the Data-Transfer Interface itself is available as open source and is freely available for anyone interested in its use.

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Principles for the Design of a Remote Laboratory: A Case Study on ERRL

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Abstract-- **Remote laboratories are getting very popular in engineering education programs. However, there are not many studies addressing the requirements and design issues of such laboratories. This paper discusses the results of a study of the requirements for developing a remote Radio Frequency (RF) laboratory for university students. This study draws on the perspectives of the students at the university, department of electrical engineering. The results are based on a research study established by 111 engineering students from France, Germany, Romania and Turkey. It investigates how students would like to use the technical content of a state of the art RF laboratory. The result of this study is also compared with the previous outcomes showing perspectives of the other learner groups of such laboratories; engineers and technicians in the technical colleges on the Radio Frequency (RF) domain. Considering the outcomes developed so far, some principles that need to be considered while designing and developing such a laboratory have been proposed. As a case study the proposed principles are implemented in a remote laboratory project. In this paper, the details of user requirements of such laboratories, the proposed principles and the implementation examples are all provided and discussed. Primarily, the general aim of this study is to guide remote laboratory platform developers towards the most effective design of their platforms.**

Index Terms— higher education, engineering education, remote laboratory, distance education, Improving classroom teaching, lifelong learning.

I. INTRODUCTION

Nowadays, based on new technologies, educators and curriculum developers are able to provide a wide range of educational alternatives for learners. Remote and virtual laboratory environments are some of these alternatives which have shown that they are potential solutions for supporting current education and providing some alternative solutions for distance learning environments [2]. However, in literature, not many studies discussing the requirements of those laboratories and the instructional design issues that need to be considered in the design of such laboratories could be found. Furthermore, as Koohang and Durante reports, the web-based distance learning technologies rely on interface design elements such as usability, visualization, functionality and accessibility which play an important role in learning [3]. Accordingly, appropriate learning theories and principles as well as user interface elements need to be considered in the design of such laboratories [3]. In our previous studies, we have discussed the requirements for remote RF laboratory applications from the educators' [2], the technicians' and engineers' [1] perspectives. This paper aims to find out the requirements from the students' perspective which is organized for the European Remote Radio Frequency Laboratory (ERRL) project[1]. How do the students prefer to study in a remote laboratory environment is the basic question of this study. The study is established on potential students of such a laboratory environment: students in higher education institutions. The main scope of this study is limited to the instructional content design issues for such laboratories. The issues that need to be considered in the sense of user interface design of such laboratories are not included in this study.

II. COURSE DESCRIPTION

Instruction can be provided with several different forms in a remote laboratory environment such as text, animations, images, figures, interactive content, video and sound based instructions. In literature several studies have been established to find the effect of these different forms of instructions on different learner groups. Those studies show that, the preferences of the target learner groups and actual performance on these different forms of instruction also differ. For instance, reading a text requires linear information processing and significant skill and effort [4]. Differently from the test, pictures' symbol system is sensory and more efficient for representing nonlinear relationships among objects [4]. According to Mayer, visual presentation of learning material enhances learning [5]. From their study, Bele and Rugelj suggest including verbal and pictorial representations for each learning page and additional animations should also be provided for the choice of the learners [6]. Mayer also suggests using words and pictures in ways that promote meaningful learning: adding pictures to words, eliminating extraneous words and pictures, placing words near corresponding pictures, and using conversational style for words [5]. Research also shows that, combination of text plus line drawings shows clear advantage in learning process [7]. On the other hand, from their study, Bele and Rugelj suggest an interactive question for the design of each learning page for immediate knowledge evaluation [6].

[1] Guest access is available at http://errlmoodle.atilim.edu.tr/ with both user name and password being "visitor"

Additionally, studies also show that students' preferences on web-based instruction for linear or non-linear ordered instructional design is also different [8]: older students prefer direct instruction. Students who are more familiar with the windows-based computer applications tend to prefer non-linear instructions. These studies show that, organization of the content and design of the instructional material as well as the feedback system are quite important for improving the performance of the instructional systems. Accordingly, before an institution can offer the most effective remote training for learners, a requirement analysis must be conducted. This study was implemented in the ERRL project in order to identify the requirements from the learners' perspective.

II. DESIGN OF THE STUDY

This work initiates from the belief that the requirements should be clearly defined before technical and practical development of a remote laboratory. The remote laboratories have two main potential groups of users: the educators and the learners. This study mainly focuses on the requirements of the learners from such a system in order to answer the following research questions:

- How students prefer to use a remote laboratory environment?
- Do they need guidance and help while studying a subject?
- In which order do they prefer to study subjects (linear / non-linear)?
- How do they like the content to be displayed?
- What are the students' attitudes toward computer mediated communication?

To answer the questions above, a questionnaire was prepared for the students as potential users of a remote laboratory. This questionnaire[2] was presented to 111 potential students from different European countries: France, Germany, Romania and Turkey. The distribution of the subjects of this study among those countries is shown in Table 1. All of the subjects are under the age of 25.

Table 1. Distribution of the Subjects among Countries

	M %	F %	Σ %
France	11 (10%)	1 (1%)	12 (11%)
Germany	14 (13%)	1 (1%)	15 (14%)
Romania	37 (33%)	16 (14%)	53 (48%)
Turkey	24 (22%)	7 (6%)	31 (28%)
Total	86 (78%)	25 (22%)	111(100%)

M: Male, F: Female, Σ: Total

2 http://www.atilim.edu.tr/~nergiz/ERRL_Questionnaire_students.pdf

As seen from Table 1, most of the participants are male (78%), which is usual according to the general gender distribution in this field. After the analyses of the requirements of the potential learner groups, the ERRL content is developed to better address the learners' requirements.

This paper analyses the target learner groups' requirements from a remote laboratory environment as a case study, describes how the ERRL content is designed to better address these requirements.

III. RESULTS

The following section analyses the results of this study according to the research questions: the quantitative data is analyzed descriptively. Since the number of female participations was very limited the results do not have gender comparisons.

A. Need help and guidance

The participants' general preferences were asked while studying any subject. According the result of this question is shown in Table 2. Most students; 55% prefer studying with someone who knows the subject well. Their second preference is studying on their own and lastly they prefer to study in groups. In our earlier study [1], this preference order was found to be similar for engineers 50%, 29% and 21% respectively. However, the technicians' second preference found studying within a group (40%) and the third one was studying on their own (13%). In that sense, technicians' preferences found to be different from the students' and engineers'. This shows that the students and engineers in general are not comfortable while studying within a group.

Table 2. Study Preferences

Q4. When learning a new subject which one do you prefer? *(Please Select only one)*	Σ %
Studying with someone who knows the subject well	55
Studying on your own	29
Studying within a group	16

Σ: Total

This result shows that, technicians do not feel as comfortable as other groups of learners while studying on their own and they need more guidance according to the other groups of learners. Most of the students (59%) believe that they need guidance while studying a new subject (Table 3).

Table 3. Need for Guidance

Q6. Do you need to be guided when learning a new subject? (Please select only one)	Σ %
Yes, I need someone to teach me	59
No, I can handle it on my own	41

Σ: Total

On the other hand, 41% of all students feel comfortable while studying on their own.

B. Preferred order (linear / non-linear)?

As shown in Table 4, most of the students (60%) prefer to study the concepts in a linear order: starting from the beginning and going through the chapters in an order. The non-linear ways of learning approaches (keyword search, read the related chapters only, and do exercises only) are their less preferable alternatives. The situation was found to be similar for engineers and technicians in our previous study [1]. However, technicians never prefer keyword search or study only the end of chapter exercises alternatives. Additionally, the percentage of technicians that prefer linear way of studying (73%) is higher than that of engineers (63%) and students (60%).

Table 4. Perceived Learning Preference

Q5. Which of the followings best matches with your learning abilities? (Please select only one)	Σ %
Starting from the beginning of the subject and go through the chapters by order	60
Searching on the keywords (by using search engine of the site or the index part of the book) and then studying on the results	17
Read the chapter that you want to know and leave the rest	14
Trying to understand the end of chapter examples & questions never read the rest	9

Σ: Total

When the similar question is asked for the web environments, the ratio for the keyword search gets higher (Table 5). On the web, technicians, engineers [1] and students also behave differently from their traditional way of learning environments. For instance, most of the technicians and engineers prefer non-linear way of instructions on the web (reach information by means of keyword), where as in the case of traditional ways of studying they mostly prefer the non-linear ways Table 4 [1]. This finding may be a sign to show that when they have a chance to reach information directly they use this feature and their habits are changing through non-linear ways of studying by the introduction of the advanced technologies on the web.

Table 5. Perceived Learning Preference on Web

Q7. When you try to learn a new subject by using a web-site, how do you prefer to study? (Please order the items below according to your preference, 1 is the most preferred one)	Σ %
Go trough the chapters in a given order one by one	36
Reach the information by means of keywords and read only the chapter you need	39
By means of questions and answers between the system and you	25

Σ: Total

C. Display of Content

When the participants' preferences were asked on the ways of the display of the content, in the first place all students prefer interactive content. While engineers' preferences are similar to the students' preferences, it is observed that technicians' first preference is figures on the subject [1].

Table 6. Preferences for Computer Based Experiments

Q8. When performing experiments on a computer I prefer: (Please order the items below according to your preference, 1 is the most preferred one)	Σ %
1-Interactive	17
2-Batch jobs	9
3-Story based	11
5-Figures on the subjects	10
6-Several problems and exercises	12
7-Games related with the subject	10
8-Animations on the subject	12
9-Text-based instructions	11
10-Sound-based instructions	8

Σ: Total

D. Attitudes toward Computer Mediated Communication

In order to identify the participants' attitudes towards computer mediated communication, the advantages and disadvantages of such platforms were asked. Table 7 and Table 8 show their responses on this issue. As seen from Table 7, the students find the geographic independence as the most important advantage for computer mediated communication.

Table7. Advantages of Computer Mediated Communication

Q10. Please select the advantages you consider important for you in computer mediated communication	Σ %
1-Geographic independence	31
2-Temporal independence	20
3-You are not embarrassing for teacher's presence	7
4-Silent (nobody disturb you)	16
5-You can find quickly elements of all past communications	26

Σ: Total

The second one is listed as the finding quickly the elements of all past communication. Temporal independence follows this and silence comes next. According to students, the least important feature of the computer mediated communication is the embarrassment of the teacher's presence. Table 8 summarizes the disadvantages of the computer mediated communication according to the students.

Table 8. Disadvantages of Computer Mediated Communication

Q11. Please select the disadvantages you consider important for you in computer mediated Communication	Σ %
1-Absence of immediate feedback for asynchronous communication	32
2-Imperfect technology	17
3-Not yet sufficient experience with the web and the Internet	8
4-Reading online especially if the amount of information to be read online is significant	27
5-You may not be certain whether other participants have received your message	16

Σ: Total

As seen from Table 8, the most important disadvantage is the absence of immediate feedback for the asynchronous communication (32%). Reading online follows it. Imperfect technology and not being sure whether other participants have received your message come next. Students mostly feel that they already have sufficient experience with web and internet. However, according to the engineers and technicians, the most important disadvantage is found to be the difficulty in reading the online feature of the computer mediated communication (39%) [1], where as for the students this percentage is 27%. This shows that, the younger generation feels more comfortable reading online.

IV. A REMOTE LABORATORY IMPLEMENTATION

As a summary, depending on the first and previous studies, it is possible to conclude that, user requirements and preferences change among different learner groups. Because of the variations in different learner groups' preferences (the students and engineers are in general not comfortable while studying in a group), the technicians need more guidance according to the other groups of learners (while studying, technicians never prefer keyword search or studying only the end of chapter exercises), the percentage of technicians that prefer the linear way of studying (73%) is higher than that of engineers (63%) and students (60%).

General Characteristics of the Learner Groups

- The ratio for the keyword search is getting higher while studying on the web
- Sound based instructions are least preferred
- Interactive content, problems and exercises, animations and figures are preferred forms of content display
- Geographic independence and quickly finding elements of all past communication are listed advantages for the computer mediated communication
- Absence of immediate feedback and reading online are the most important problems of the computer mediated communication.
- The younger generation feels more comfortable as they read online
- The learners' habits are changing through non-linear ways of studying by the introduction of the advanced technologies on the web

E. ERRL Design Principles

As a remote laboratory implementation in the ERRL project, the following principles have been followed as the guidelines for the design of the ERRL system.

Instructions for different learner groups should be provided differently:

From the requirements study, it is understood that the different potential learner groups' requirements and expectations from the ERRL system also differ. In order to satisfy this requirement, the following design approaches were used: Reading texts in the study theory part and experiments are arranged according to these needs of different learner groups. Therefore, the content is divided into three levels as; basic, intermediate and advanced. That is, the content is simplified or enlarged according to the learner groups' requirements. Also, the ERRL platform is designed as flexible enough for offering the possibility to change the lectures from a semester to another and to add new experiments that correspond to these lectures. For this, the content is defined in the ERRL system as learning objects which defines smallest units of instruction that can be reused in different contexts [11], [12].

Support both linear and non-linear presentation of the content

From the study of requirements, it is understood that, in web-based environments, learners' intention on non-linear instructions become higher. However, they still prefer to use the linear way of studying materials. Accordingly, the ERRL system, providing both ways of instructions, has been designed. Learners do not necessarily have to follow each instruction in the system in a linear order. They shall be able to just reach the necessary information which is needed at the moment of the work. Accordingly, the system must be self-directed and also have to support non-linear instructions. For instance, if an engineer tries to get a little information about a feature of specific equipment and if the learner has to go through the whole content, it might also be boring or annoying. The system must provide the necessary information at the moment of need. On the other hand, the system should also support linear instructions and guidance whenever needed. In the ERRL system, the learning content in different studying orders has been designed to satisfy requirements of different learner groups. The instruction is provided in a highly guided manner. All the necessary instruction is given in a predefined order for beginners. Parallel to this, the same instructions are organized as an experiment manual that shows the instructors in order to quickly start the experiment for intermediate or advanced level users. Similarly, in the design of the teaching tool on how to use each piece of equipment, the search facility and the questioning and answering features are added. If the user needs some specific information about any piece of equipment, then learner can write the keyword or ask the question in the text field of "Search for:" part of the system. When the "Submit" button is clicked the results of the search will be shown in the right part of the system again. These results are listed as links in the form of text documents, videos, audios or other forms that are available in the Learning Management Systems' (LMS) database. On the other hand, experiments and study theory parts of the ERRL includes many hyperlinks providing direct access and guidance about equipment and content. In this way, the user doesn't have to linearly search all content in order to find the related material.

Forms of Instruction - Not many sound-based instructions

The ERRL content has been developed and distributed into different skill levels considering the target user groups' requirements. There is very limited movie or sound based instructions in the ERRL system as alternative for the other forms of the instructions. In this way, the users can select the proper content for themselves and the learners are free to study the concepts repetitively in different forms of training. Also, where possible, the lectures include suggestive animations and simulations that decompose and describe the physical phenomenon under study, in order to be clearly and appropriately understood by the students. Interactive animations used within the lectures can allow for a multitude of scenarios, creating unique situations in response to student inputs.

Providing interactive content such as exercises and experiments

As it is suggested by the literature, the experiments and exercises are very important for the engineering education [10]. Accordingly, the ERRL system is designed to provide as many exercises as the learners want to practice in a specific content. As seen from Figure 1, the learner can set the experiment parameters and repeat the experiment several times.

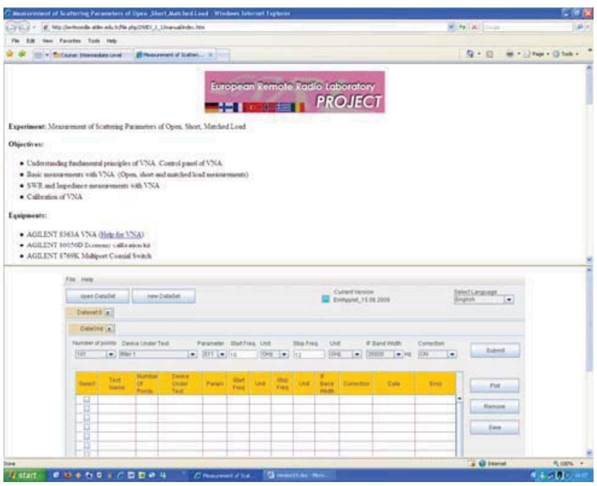

Figure 1. ERRL Experiments

This activity also provides trial-and-error type of learning approach for the ERRL learners.

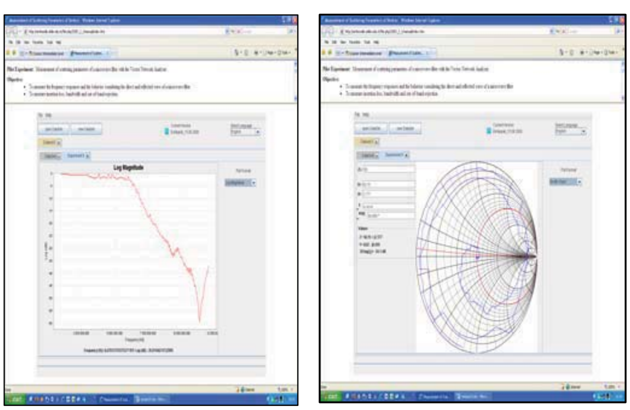
Figure 2: Analysing Experiment Results

As seen from Figure 2, they are also able to analyze the results by showing them in different graphical formats such as Smith Chart and Log Magnitude, to compare and choose the most suggestive one.

Providing a good feedback system

In the ERRL system, in order to provide feedback on the learning performance for both learners and instructors, the assessment system is organized as a skill level test, experiment and equipment test. A Skill level test is advised to be taken immediately after the registration of the system. It can be taken as many times as the learner requests. The main purpose of this test is to understand the beginning skill level and progress in the skill level of each learner. These pre-course assessments that identify areas where relevant background knowledge is missing or prone to misconceptions can serve to revise the curriculum, encouraging talk and curriculum development between instructors both within and across departments.

Experiment tests are applied immediately after the implementation of each experiment. Tests are generally short, and as they are multiple-choice, they are useful for immediate quantitative assessment of student understanding. The experiment user interface covers both theoretical backgrounds for the experiment as well as the experiment itself. The ERRL on-line tutorials with built-in assessments or interactive components combine instruction and assessment. Feedback from assessments, such as item analyses, can be used to inform instruction, enabling the instructor to target the specific components of the lessons that students find troublesome. Another assessment used method is: immediately after studying each experiment. The experiment test items cover both theoretical and experiment specific issues to be tested based on the objectives of the experiment. Each test item about the experiments is defined by describing the following details. Accordingly, each item in an experiment test is defined by its objective as well as if it serves for one of the knowledge, skill or competence purposes. There are at least 3 test items for each experiment objective. Also the number of knowledge, skill and competence type questions is evenly distributed throughout each test. In order to pass the experiment exam, learners are usually asked to be successful for at least 70% of each knowledge, skill and competence type of questions. Learner's current skill level is calculated by using the experiment test results. According to the request of the learner, a summative evaluation report is prepared to show the progress of the learner from the starting point to the current level. This report is based on the learner's progress on each skill level. More detailed reports on learners' progress in each test as well as each test item and an advisory report is also prepared for the learners to better facilitate their learning.

Another test that is implemented in the ERRL system is the equipment test. The main purpose of this test is to assess the learners' knowledge level on each piece of equipment. Learners are asked to pass this test before starting any experiment that requires specific equipment to be used. However, some skills such as the ability to handle the measurement devices may not be easily assessed. Accordingly, the questions are organized to focus on the equipment construction, how it works and the measurement possibilities. The equipment test content is prepared specific for each piece of equipment; however the testing system strategy is the same for the experiment tests.

V. DISCUSSIONS AND CONCLUSIONS

In this study, the learners' requirements specific to this case study have been collected and analyzed. The ERRL system has been developed based on these principles. The feedback from the sample groups from different countries demonstrated that the above principles are a good approach for the web-based learning and provided us the necessary certainty to continue the work in this direction. For future studies, this system is planned to be integrated into the curriculum and will evaluate the success of the system didactically by addressing these principles. Although these principles are developed according to this specific case study, it is believed that they can be improved and implemented into any web-based instructional system.

Currently we are adapting the ERRL system to curriculum of the related courses in the Electrical Engineering Program of the University by creating technology enhanced learning environments. In that context it is believed that this study will guide the instructional designers of such systems. Additionally, by establishing similar requirements analyzes, the educators may also adapt the ERRL system or other similar systems to their environments. Our preliminary results based on the created technology enhanced learning environments which is designed through the ERRL system according to the requirements of our learner groups, are promising.

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Supporting Person-Centered Learning: Does the Choice of the Learning Management System Matter?

A case study with Moodle, Fronter and CEWebS

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Abstract—**One challenge in the successful implementation of a blended learning scenario is the choice of the appropriate tools. The general question behind our practical approach is: "How well do different eLearning solutions provide functionality to realize a blended learning course, which is designed according to specific educational principles?" To approach a response to this question for our case, one typical person-centered blended learning course was implemented in three different eLearning solutions, namely Moodle, Fronter and CEWebS. The resulting realizations of the course and the necessary actions are documented and compared in this paper. The investigated eLearning platforms provided sufficient functionality to accomplish many of the basic tasks in the daily course routine more or less effectively. For tasks beyond the basic functionality of a solution, either the employment of extensions or customizations were necessary, resulting in an implementation that was in some aspects quite elaborated.**

Person-centered learning; blended learning; learning management systems

I. Introduction

In our understanding blended learning scenarios should be developed, in the first place, based upon specific learning paradigms and not on what a technological solution can offer. Since we aim to promote *person-centered, technology enhanced learning*, we see ourselves confronted with the question: Do current well known learning management systems sufficiently support person-centered learning designs?

PCTEL or Person-centered Technology Enhanced Learning [1], [2], [3] aims to facilitate a meaningful learning process by combining a humanistic, person-centered pedagogy with thoughtful use of eLearning technologies. In the PCTEL-approach learning is based on the values of humanistic-psychology developed by the renowned psychologist Carl Rogers [4] and on a deliberate use of eLearning-technology.

How does all this fit together? Can the person-centered approach be combined with technology enhanced learning in an enriching way? Learning is more likely *significant learning*, if it involves intellect and feelings [5]. The difficult issue with this concept is that the inclusion of feelings into a learning process does not happen automatically in a classroom environment. Inclusion of the whole person into the learning process is fostered by certain attitudes between teacher, professor or lecturer and his or her students. These basic attitudes are: *genuineness, acceptance* and *empathic understanding* [5]. Through living and communicating those attitudes so that learners can perceive them the teaching person becomes a facilitator who is providing a confident basis for significant learning.

In contrast, an eLearning situation lacks direct personal contact, but it can be employed to reduce administrative and organizational overhead and to make intellectual content easily accessible whenever learners request it [6]. Additionally online environments (e.g. communication boards) can provide space for exchanging ideas, opinions, feelings and meanings within the course community in a way that complements the socially rich but time-limited face-to-face meetings.

To sum up, person-centered scenarios benefit from the employment of eLearning elements by providing learning resources and by reducing administrative costs which allows for more person-centered communication in class, as well as supporting interaction between meetings. Consequently, in our case a central question arose: "*Which learning management systems meet the demands of person-centered technology enhanced learning scenarios best?"* An accompanying question would be: *"What are the major differences between various learning management systems in light of supporting person-centered blended learning?"*

The rest of the paper is organized as follows. Section 2 presents the methodology of this research. Section 3 details the case course structure whose three different implementations are discussed in detail in Section 4. Conclusions and final recommendations are given in Section 5.

II. Migrating an Online Course

Instead of analyzing the eLearning platforms with a fixed catalogue of criteria [7], [8] one typical course from the *Research Lab for Educational Technologies* was implemented in different eLearning environments. The underlying purpose of this approach was to focus on the implementation process, rather than on criteria analysis.

The example course was “Project Management”, which was conducted in the summer term of 2009 and initially delivered through CEWebS services. For the purpose of this research this course was migrated into a Moodle installation set up on a personal university Web space for testing Moodle, and into a testing course provided by the University’s computing centre for testing Fronter.

III. The Source Case Course – “Project Management”

The source case course for this migration, the course on project management, was conducted in the summer term 2009 at the Faculty of Computer Science of the University of Vienna as a combination of a lecture and lab course. The course was about learning the basic concepts in classical and agile management. Central topics were managing IT and interdisciplinary projects, controlling, cost estimation, risk analysis, organizational techniques and conflict management.

Students had to accomplish single and group assignments. The single assignments consisted of planning a small project, while the group assignments included planning of a bigger project according to predefined milestones and deliverables, and the development of a prototype.

The final student grade was composed of the results of the single assignment, the group project evaluation, several instructor evaluations of milestones, peer evaluations in the lab course and a final exam. A pattern-based blended learning scenario for project management modelled in UML is depicted in Fig. 1. Additional attributes of the patterns or so called stereotypes [6] are illustrated in Fig. 2.

A. Lectures

In the lecture (Fig. 3), lecturers and external guests from the field of project management held their lessons. Besides the presentations in class and publishing of lecture resources (e.g. PowerPoint slides) reaction sheets were employed.

Using the reaction sheets, reactions from students were collected online and taken into account in further proceeding of the course.

B. Lab Course

In addition to brief lab lectures and exercises (Fig. 4) a major task was the group assignment: Students were free to choose a project for being developed in groups of 2 - 5 persons.

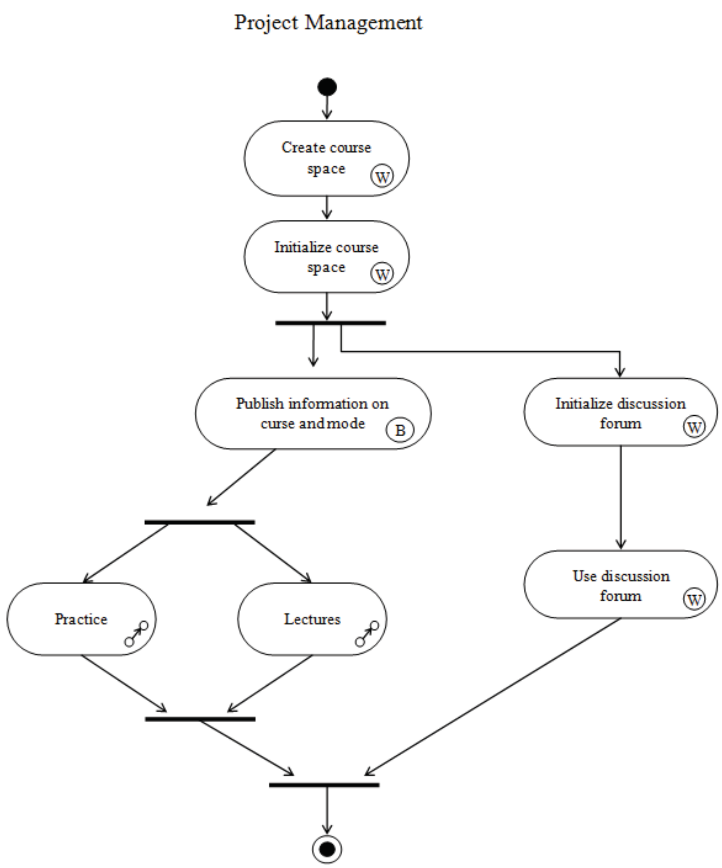

Figure 1. Activity sequence in Project management course

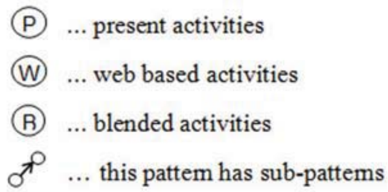

Figure 2. Stereotypes and their denotation

After a few weeks of development a peer evaluation was performed. The results of this evaluation were used to improve the reviewed projects. Additionally, each student worked on his or her own single project, which was reviewed by a tutor.

IV. Three Equivalent Solutions?

We briefly introduce the three eLearning solutions that are the subject of the case study. The course on project management had originally been developed for use with CEWebS and, vice versa, CEWebS had long before that been originally developed with PCTEL support in mind. Accordingly, we start with presenting the CEWebS implementation (Fig. 5) and proceed by discussing the transformations into Moodle and Fronter, respectively.

A. CEWebS

CEWebS stands for *Cooperative Environment Web Services* and was developed at Department of Knowledge and Business Engineering and the Research Lab for Educational Technologies at the University of Vienna [9].

The CEWebS-approach to provide an eLearning solution differs from the approach employed in the development of other learning management systems: *"Instead of relying on a central learning solution provider, we try to foster the exchange of tools and ideas on the organizational level"* [10].

CEWebS is a "homegrown" solution and it is built and adapted to the specific needs of the Department of Knowledge and Business Engineering and the Research Lab for supporting courses in a way to support person-centered, but also other interactive blended learning courses. Since the winter term of 2003 more than 100 courses (their eLearning components) have been delivered in CEWebS.

B. Migration to Moodle

Moodle is Open Source software and licensed under the GNU General Public License and therefore it might be altered, which makes it easy to be adopted or expanded for one's own purposes. The migration of the case course to Moodle was performed using version 1.9.5+.

While transferring the course on project management to Moodle we had to analyze the possibilities of this platform to support various aspects of person-centered learning and the development of specific activities needed for our case course.

- *User roles:* Standard user roles in Moodle match the following roles in CEWebS: the *Administrator* and *Course Conductor* are one role in CEWebS and correspond to the *Administrator* role in Moodle; other user roles in CEWebS are divided into two possibilities – either a user is assigned to a group, then the user-role is comparable with the *student role* in Moodle or if the user doesn't belong to a group, he or she is treated as guest. Additionally, Moodle allows the creation of a custom hierarchy of roles that can be assigned to users at the site, course or individual activity level.
- *Basic information providing - Wiki, Webpage, Lessons:* The basic idea of providing information in CEWebS is realized through a Wiki. In Moodle either a Wiki, linked Webpage or the Lesson module can be used for this purpose. The Lesson module seems to be the most appropriate one, because of its richest text-design possibilities.
- *Grouping of content:* Grouping of content in Moodle can be achieved by adding a Webpage resource, which offers links to the corresponding resources. To avoid that too much information is displayed, content can be placed in outlying sections (e.g. the course admin can create some reaction sheets in *section 7* and then limit the number of topics to two, so only *section 1* and *section 2* will be displayed – still the reactions sheets are available and can be referenced by a hyperlink). There are also some third-party plug-ins that can provide course structures which serve the similar purpose a bit more automatically.
- *Participants – Groups:* For sending mass-mails the most appropriate Moodle functionality is "add/send message" available in the overview of the participants.

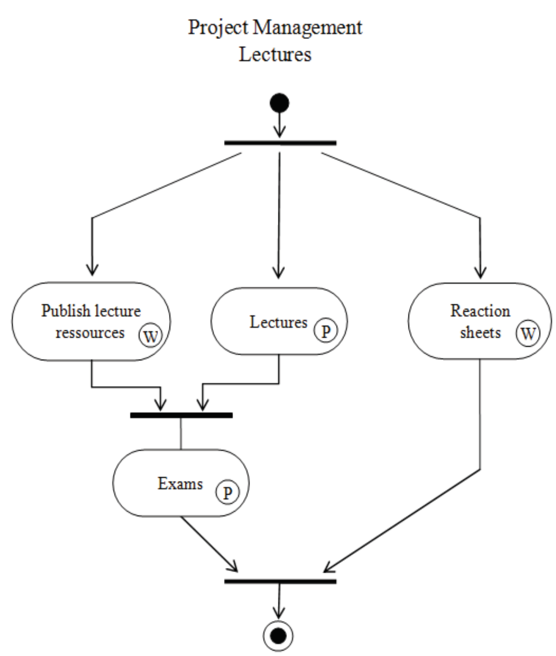

Figure 3. Activity sequence for reading lectures (VO) in Project Management course

Forums can also be used for distributing important bits of information to all subscribed students (students who opted for receiving copies of all the posts from particular forums via e-mail).

In Moodle there is a built-in tool to create groups. With the experimental feature called *"groupings"* groups within groups might be created. An even more differentiated group management, which is similar to the CEWebS group management, is achieved by using an additional Moodle plug-in [11]. With the help of this plug-in users are able to assign, move and remove themselves to/from groups. In order for students to assign or remove their colleagues to/from groups slightly stronger editing privileges concerning user accounts have to be assigned to them at the course level.

- *Assignments:* In our course on project management students have to upload their work, so that it can be reviewed by the lecturer, tutor or course conductor. Therefore a service is provided in CEWebS. In Moodle this task is achieved by using the *Advanced Assignments* activity module, where single user uploads are possible either as individual assignments or as uploads of a solution for whole groups. Group uploads might be carried out by all group members, but with an extra plug-in, with a possible limit to one upload per group [12].

  Although Moodle's Assignment tool seems to be the best match for any assignments at the first glance, this instrument cannot provide a feature that allows students to take a look into other students' solutions. This can be solved by using other built-in tools like *Workshop* or *Database*. Workshops are particularly convenient if peer assessment amongst students is to be conducted.

- *ePortfolios:* ePortfolios can be implemented in Moodle using a plug-in provided by Exabis Internet Solutions [13]. Unlike in CEWebS, when using this plug-in students can decide whether they want to share their portfolios with other course participants or not.

- *Reaction sheets:* CEWebS provides a comfortable way to collect the reactions of course participants. In Moodle reaction sheets are either realized by using *Online text* assignments or using the *Feedback* module. This is a third-party module that will be included in the standard package in version 2.0. It is quite suitable for creating different kinds of more or less complex questionnaires. It also enables the students to view the results of these questionnaires, not only the teachers. If reaction sheets are implemented as simple online text assignments they cannot be displayed to all students.

- *Discussions:* A discussion is simply realized by using a forum. If more forums are needed they might be grouped as described under *Grouping of content* as one initial menu item.

Once the user is accustomed to the amount of options and features, Moodle is easy to use and straightforward. However, special adoptions in the course design to meet communicative and person-centered-supporting requirements are sometimes a bit tricky. Nevertheless, additional modules or plug-ins can be installed easily. Further customization is possible by altering or extending the source code, though rather resource-consuming. Therefore, the preferable method of fulfilling this platform with all features needed to implement a course like Project management is the smart use of built-in features together with various extensions. Including useful plug-ins in the platform or integrating external applications can contribute to success, but it certainly leaves a lot of potential for further improvements on this platform [14].

C. Migration to Fronter

The migration of contents to Fronter was conducted with Vienna University's Fronter Installation provided by the ZID [15].

"Fronter is a virtual building, structured into rooms. Each room is equipped with the tools required to empower the collaboration and learning activity in that room. The room owner invites members and assigns rights according to each member's role in the room." [16]

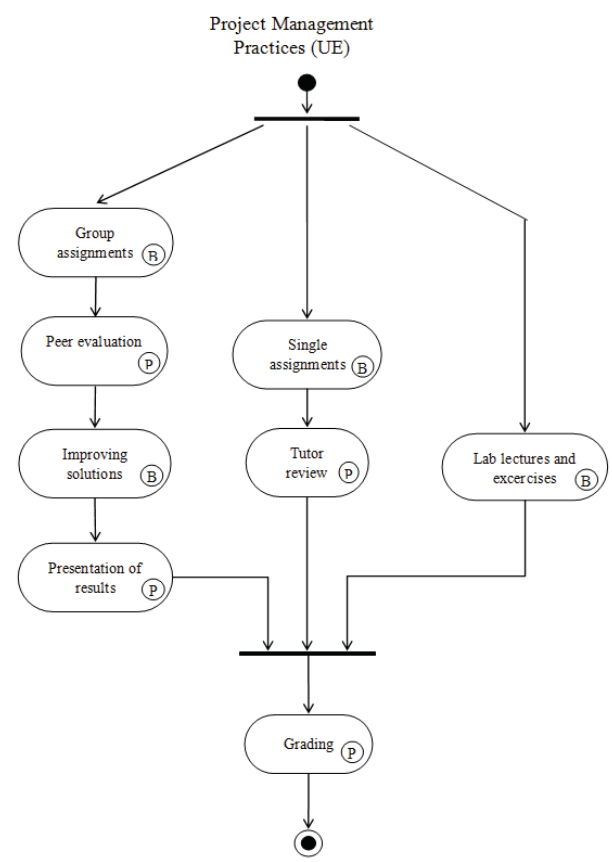

Figure 4. Activity sequence for practice (UE) in Project Management course

While transferring the course on project management to Fronter the possibilities of this platform to support various aspects of person-centered learning were analyzed in detail.

- *User roles:* The user roles in Fronter are, at least in the configuration from the ZID, divided into *lecturers, students* and *tutors.* Tutors have in the default case the same privileges as lecturers.
- *Basic information providing - Wiki, Documents:* Information can be provided as a page, article message or wiki. Sites might be designed and placed within the content-frame in different positions. It is also possible to add and remove site elements.
- *Grouping of content:* Fronter has the ability to use folders within many tools (e.g. discussion boards, resources) so grouping is done in a similar way as with CEWebS and more easily achieved than in Moodle.
- *Participants – Groups:* The participant information can be explicitly displayed in Fronter under the specified menu-item. Mass-mails can also be sent easily to all course participants.
- *Assignments:* User uploads are realized with the specialized tool. Users simply upload their solutions and lecturers are provided with the possibility to comment and rate the uploaded solutions.
- *ePortfolios:* Fronter's ePortfolio feature allows unrestricted visibility of the attainments of all course participants (not only teachers can see them or students who share their profiles with each other). The emphasis lies on a reporting functionality, but a satisfying handling of achievements is possible as well.
- *Reaction sheets:* Although Fronter has some features to upload text (for collecting reactions) or to conduct surveys these tools are not sufficient to manage those tasks in a straightforward way. Especially the survey tool cannot be used to implement questionnaires. So in this respect Fronter is not applicable.
- *Discussions:* A discussion is simply realized by using a forum. Different forums are easy to create and might also be organized in folders.

In general Fronter is easy to use and designed properly. However, Fronter is limited to its set of features and cannot be customized or extended as it is proprietary software, although it is presented as *Open Source* in the brochure published by the manufacturer [16]. Fronter, in our perception, lacks the ability to collect reactions from students in a *straightforward* way.

In Moodle even slighter shortcomings were solved with workarounds or extensions. In Fronter this is, thanks to the closed source policy not possible. However, if a learning scenario fits in with the technological possibilities offered by Fronter, the latter can be very productive. Still, we pose the question: Is it appropriate that the availability of a technological solution should guide the learning design?

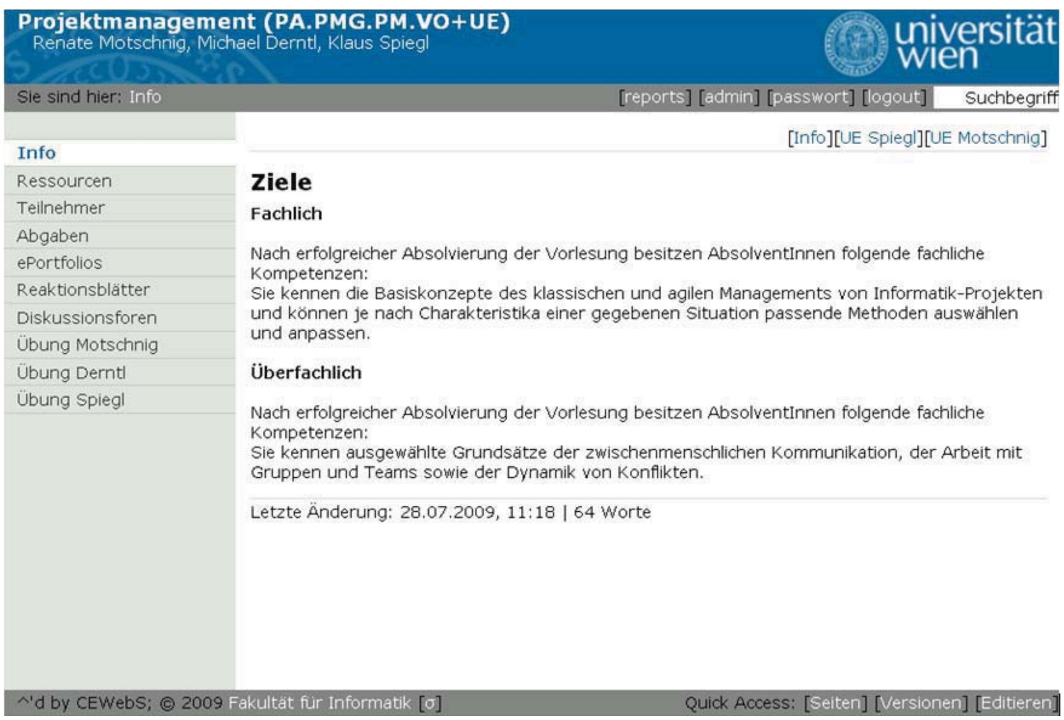

Figure 5. Screenshot of Project Management course in CEWebS

V. Conclusions

A successful implementation of a blended learning scenario according to the pedagogical and didactical principles of a person-centered approach was found to be - in an effective way - dependent on the choice of an appropriate eLearning solution.

Implementing an actual course in the field of project management was, from a technological point of view, in Moodle fully and in Fronter partly successful. Moodle provided several features and a good level of configuration for workarounds. Thanks to Moodle's Open Source license and numerous community contributions a course in Moodle was technically equal to a course in CEWebS. Fronter lacked some features, like the reaction sheets and was, because of its proprietary license, neither adaptable nor extensible. Fronter still might be a good choice for many standard blended learning scenarios.

From a practical point of view, however, the realization of the course on project management in Moodle and in Fronter did not completely satisfy the specific needs of a person-centered course design. Indeed Moodle provided enough features and usability, so that from a student's perspective, there would be – except from different interface design – no big difference. Nevertheless, an instructor would have to use some elaborated workarounds and customized extensions. All in all a lot of work had to be done to realize such a course. In Fronter not too much extra workload for the course designer arose, because a one-to-one implementation of the course was not fully possible.

Fronter provides well designed learning workflows and many specialized easy-to-use tools. As such it seems to be optimized for a defined learning purpose. Even if such a learning purpose is broadly and well defined, it cannot cover all learning approaches. In our case a person-centered approach was not completely implementable in this environment. In general it seems that for non-standard learning approaches the flexibility and openness of Open Source solutions remains indispensible.

The authors' personal conclusion regarding the migration to Moodle is that many elements of a course can be realized right away, but if you need more than a usual learning management system can offer, a more or less time consuming search for additional solutions becomes necessary. This fact was indeed an enriching experience. However, in certain stages the knowledge of experts turned out very helpful to accelerate the solution of problems and to point out new, even more elegant and practicable solutions. Moodle is without doubt a valid alternative to a specialized platform like CEWebS, but as long as the best fitting solution is supported and updated regularly, there is no need to "change the winning team". Trying to generalize our findings for a broader audience, differences in usability would even weigh more if students and instructors had less technical expertise.

Although eLearning technologies underwent a rapid development in the last years, the choice of an adequate solution is still an essential step in a successful and effective realization of a blended learning course. Especially in the field of eLearning technologies, the knowledge of experts proves once again as a time-saving and enriching enhancement to own efforts.

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Evolutive Mechanism for E-Learning Platforms

A new approach for old methods

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Abstract—**Since the beginning of men, knowledge distinguishes us as a species and has become the key to our own evolution. Humans have a complex psycho-pedagogic model, the result of millions of years of evolution. This model compromises very often the educational structures, because each of us – despite we can be inserted in specific groups, have a personal learning curve. Like nature, that develops special strategies for the evolution of the species, it is possible to find the correct individual learning path, using one of the oldest Mother Nature mechanisms – evolutive genetic. Using tools like JAVA, XML (eXtensible Markup Language), an open source LMS (Learning Management System), i.e. Moodle, a standard as SCORM (Sharable Content Reference Model), all controlled by a GA (Genetic Algorithm), it is possible to achieve a flexible platform to help all the educational process actors. The goal is to create a self universal monitoring and learning system,which follows the progression of individual learning – by using a mathematical function applied to a genetic algorithm, maximizing the results and achieve the subject "learning curve".**

Keywords: Java, XML, SCORM, Genetic Algorithm

I. Introduction

In current societies the growing need for a fast acquisition of knowledge, as well as the need to maintain the one already acquired, has led to the birth of various concepts of learning, such as the E-Learning.

However, the proliferation of various platforms and associated philosophies has not always achieved a full interaction between those who are learning and those who are transmitting the knowledge. The fast pace of modern life does not allow us the time to attend assisted classes and the aversion older people tend to feel towards new technologies are determinant factors for the global results not matching the expectations when it comes to the learning process.

In this article, the authors suggest a new transversal approach to the concept of E-Learning by using GA, Java and a LMS, SCORM compatible, thus fully innovating the applicability of the concept of E-Learning, taking it to a whole new level.

2nd Section – Presents the GA structure, and the statistic support function.

3rd Section – Presents the KB and the communication path structure between the LMS, the GA and the user.

4th Section – Presents the objectives and conclusions of the work done until now.

II. The Genetic Algorithm

The genetic algorithm has an important role in implementing this solution, since its performance will greatly affect the final results. It should be as dynamic as possible in order to achieve various goals, according to the predetermined guidelines. This should be achieved by giving weights to the cognitive profile or profiles, which are meant to be improved. The basic idea is to get the "fitness function" to be improved as much as possible in order to get a better approach to the most correct Knowledge Block, according to the previously achieved results.

The student results after an activities sequence build a set of binary values. The idea is to maximize the minimum obtained by the individual, i.e., find what difficulties are visible and redirect all the intellectual effort to overcome the problems, never forgetting the positive objectives already achieved.

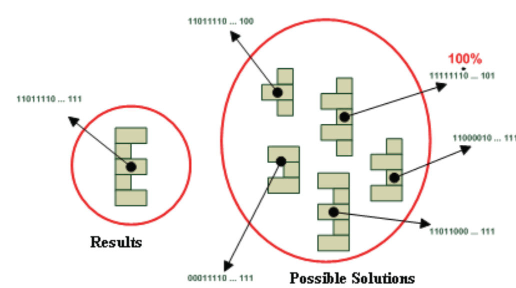


Fig. 1 – Binary correspondence of the population and possible solutions

The GA will select the KB that matches the student's difficulties. If the match is not 100% exact, 80% will be considered a fair value in the acquisition of the new block.

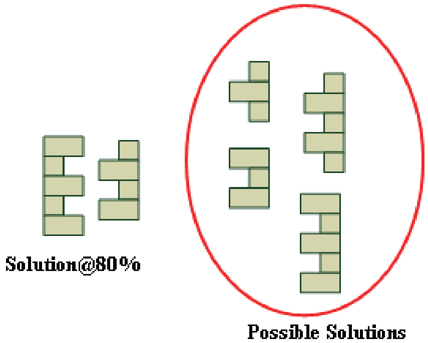


Fig. 2 - Solution @ 80%

The 100% match will be an ideal situation that the GA mechanisms will try to achieve.

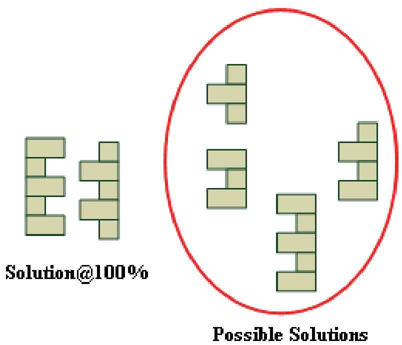


Fig. 3 – Solution @ 100%

This ideal situation will be only achieved after several cycles of study of the behavior of the individual. This ideal situation is also dependent on the availability of the block that has the desired binary value.

A. The Statistic Support Function

The chi-square is defined as a discrepancy measure between the observed frequencies and the expected ones (Fig. 4). [1]

$$Q = \sum_{i=1}^{k} X_i^2$$

Fig. 4 – Chi-square distribution

The GA uses this discrepancy measure, as its evaluation function. The obtained value will be used as a weight, to select the best candidate block.

$$x^2 = \frac{(o_1 - e_1)^2}{ej} + \frac{(o_2 - e_2)^2}{ej} + \ldots + \frac{(o_k - e_k)^2}{ej} = \sum_{j=1}^{k} \frac{(o_j - e_1)^2}{ej}$$

Fig. 5 – Chi-square distribution in extended form

The two observation tables (Fig. 6), represents a possible situation of what is sought as a final value - the expected, and that in "simulated reality" is obtained - obtained. The difference between what is expected and what we get is the deviation that must be compensated to achieve the objective - the expected value. In the simulation (Fig. 6), there are two blocks to simulate a process of classifying a given knowledge block. As it is observed in the (Fig. 6) illustration, χ^2 suffered a decrease from the 1st to 2nd KB, which can be understood as an improvement in the GA orientation, as the 2nd block to approach more of the individual's cognitive reality. It is still observed - and in spite of the illustration represents a random simulation of what is desired, that the orientation of GA is forced immediately when the discrepancies between expected values and obtained values are significant (between points 5 and 7 in the χ axis in the graph to the right, and between 5 and 8 in the graph to the left).

The theory is based mainly on the following two assumptions:

- H_0 is ignored until the learning curve of the individual is understood;

- H_0 is considered for future evolutionary terms after 1st premise has been achieved;

The use of the two hypotheses is due to the fact that the 1st objective is to understand the cognitive reality of the individual, and then improve it.

B. Algorithm for Individual Cognitive Sequence (10 samples example)

(1) Establish objective to be reached (0-100% or 0-20);

(2) Start ranking process (w/ sample = target);

(3) Get cognitive binary of the individual;

(4) Perform statistical operation on results;

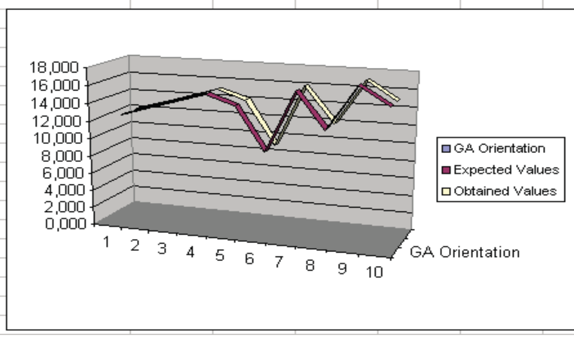
(9) Repeat (1) at least 9x (or as desired);

(10) Get Final Sum;

(11) Apply acquired weight (next module=objective to be achieved + obtained weight);

(12) Repeat (1) N times until obtain binary or objective;

Theoretical Cognitive Evolution Model - Memorization (Based in Chi-Square)												
	Observations										Average	
Obtained Values	12	13	14	15	14	13	10	12	17	15	13,5	
Expected Values	14	13	14	15	16	15	14	14	15	16	15	
	0,29	0,00	0,00	0,00	0,25	0,27	1,14	0,29	0,27	0,06	2,560	GA Orientation
Obtained Values	12	13	14	15	14	9	16	12	17	15	13,70	
Expected Values	12	13	14	15	14	9	16	12	17	15	13,70	
	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,000	GA Orientation



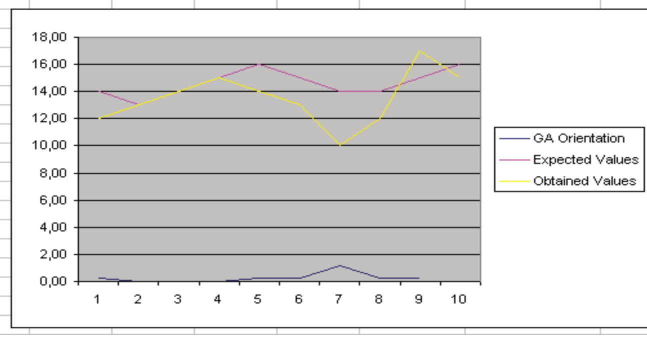


Fig. 6 – Theoretical Cognitive Evolution Model – Memorization

The algorithm begins by setting up a target, regardless of prior knowledge of the cognitive profile of the individual. The sequence (1 to 4) will be repeated at least 10 times and the value statistically treated to obtain a weight. The result will be used in obtaining the next module by the GA, with the aim to get closer to the maximum desired.

III. The knowledge block

The Knowledge Block (KB) is a simple structure that has SCORM compatibility and a binary codification, allowing the GA to be the most suitable choice to which specific case.

TABLE I. KB Coding

Reserved for Future Use	***Educational Level***	***Cognitive Profile ID***	***KB difficulty level***
00000000	00000	000	0000000000000000

Regardless of the used operator – crossover, mutation or both, 16 bits are up front considered enough for a KB selection to be uploaded in the LMS, without the risk of a premature convergence into a specific solution by the GA.

TABLE II. KB Difficulty Level

Binary Value	***Decimal Value***
0000000000000000	0
…	…
111010111000110	9,20 ≈
…	…
1100110000000110	15,94 ≈
…	…
1111111111111111	20

$$20_{10} - <65535_{10}><1111111111111111_{2}>$$
$$9{,}20_{10} - <X_{10}><Y_{2}>$$

$$X = <30150_{10}><111010111000110_{2}>$$

After being provided the results in decimal base, by the GA, those will be converted by an internal mechanism - a 3 simple rule in order to achieve the corresponding binary value of KB closer to the desired.

TABLE III. KB Cognitive Profile ID

Cognitive Profile	***Binary Representation***
Logical-Mathematical	000
Linguistic	001
Musical	010
Spatial	011
Naturalist	100

Considering that of the 10 (ten) cognitive profiles universally recognized [2], only 5 (five) will be subject to analysis, since the remaining four – Corporal, Intrapersonal, Interpersonal and Existential can not be considered in the context of this work, because they are virtually impossible to quantify due to their strong abstract nature, we therefore will need only a 3 bit code to represent them.

TABLE IV. KB EDUCATIONAL LEVEL

Educational Level	*Binary Representation*
1st Grade	00000
…	…
Bachelor's	01000
…	…

In a similar way, the remaining 5 bits will identify the educational level best befitting the KB. The choice of such a wide identifier has to do with the possibility of reaching 32 possible levels of identification, in a specific educational system. In Portugal, these values can easily go up to 23 levels. The exchange of all the information between KB and GA will be made through XML files. The LMS, in turn, will provide the user with the KBs appointed by the GA, in a dynamic way, changing the links, according to the information received.

```
<language>
      <typename>
            <tysource sourcetype="imsdefault"/>
      <tyvalue>German</tyvalue>
      </typename>
      <contentype>
            <referential>

                  <indexid>language_01</indexid>
            </referential>
      </contentype>
      <proficiency profmode="OralSpeak">Excellent</proficiency>
      <proficiency profmode="OralComp">Excellent</proficiency>
      <proficiency profmode="Read">Good</proficiency>
      <proficiency profmode="Write">Poor</proficiency>
</language>
```

Fig. 7 – XML example of a record containing information of classifications

The exchange of all the information between KB and GA will be made through XML files (Fig. 7) [3]. The LMS, in turn, will provide the user with the KBs appointed by the GA, in a dynamic way, changing the links, according to the information received.

IV. OBJECTIVES

The authors aim at implementing a new paradigm, creating a system that, in most cases, will manage without the physical presence of a tutor. It will allow the student to have greater flexibility in learning, since there will be an exclusively – if it is so desired – man-machine interaction, with no third party involved, thus reducing certain constraints to progress, that might occur should it be done under the traditional methods.

V. CONCLUSION

The theoretic part of the work is ready. The authors have already designed all the interactions and mechanisms that will allow to proceed to the development phase. Field-testing will occur during this development. There is already a partner – a local kindergarten which has volunteered to test the GA results. In the future, it will be taken into account the possibility of this solution to include the capacity to make several choices of KBs, allowing the improvement of two or more cognitive profiles.

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Session 05B Area 3: General Issues in Engineering Education - Improving students performance

Personal Learning Environments in a Global Higher Engineering Education Web 2.0 realm

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A Proposal for the Evaluation of Final Year Projects in a Competence-based Learning Framework

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Personal Learning Environments in a Global Higher Engineering Education Web 2.0 Realm

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Abstract—**This paper presents investigations on formal and informal requirements for personal learning environments taking into account students' personal and social learning practices. The potential of global Web 2.0 educational service bundles and informal learning communities, as well as their recommendation by educators are addressed. A scenario showing how these new paradigms can be integrated in engineering education as a way to bring together personal and social learning practices is drawn.**

Web 2.0; Personal Learning Environments; Mash up; Social Learning; Personal Learning; Educational Widgets; Learning Communities

I. Introduction

A hidden revolution in higher engineering education is currently underway for multiple reasons. First, the students entering the university are digital natives often with higher technical skills than their educators, who are digital immigrants. Second, Web 2.0 technologies enable students to mash up the learning resources, the learning services and the learning communities of their choice. The same technologies also enable educators to move from blended learning approaches to blended contents (blogs, wiki, repositories) and blended learning environments called personal learning environments [1]. Such environments will progressively replace, or at least complement, learning management systems (LMS) in the coming years in a move towards personal and social learning environments. Third, students can access open learning repositories outside their institutions.

The opportunity for students to build their own learning environments or socio-academic contexts, as well as their own learning networks or communities has always existed at a local level (campus or hometown). People enrolled in the same study programs or courses are used to meeting in social settings to do homework or prepare exams. With the above-mentioned trends, higher engineering education institutions should have a closer look at these informal personal and social spaces and practices, which are expending at a global scale and are giving students access to an unlimited realm of potentially valuable resources and experts. In addition, educational scientists consider the construction of learning environments and the integration of learning communities as being an integral part of the learning process. Especially, it helps students to develop the high-level skills and competences required by their future employers. Hence, a challenge for academic institutions is to integrate in a proper way the students' practices and environments in the existing institutional ones in order to take advantage of them. Another challenge is to support the students in their informal learning practices and in the construction of their learning environments and networks as a next step in increasing digital literacy. Students nowadays need recommendation regarding trusty resources and networks that go beyond the traditional brick-and-mortar universities.

The ROLE European integrated research project (http://www.role-project.eu/) has been investigating since February 2009 the interplay between personal learning and personal learning environments. 16 partners with educational, technological and commercial background collaborate in a multidisciplinary and intercultural manner to sketch the next generation of personal learning environments that can contribute to changes in the education paradigm as described in Sections II and III. The rest of the paper concentrates on results regarding formal and informal requirements for personal learning environments (Sections IV, V and VI), taking into account the peculiarities of personal and social learning. The potential of Web 2.0 service bundles and their recommendation by educators are tackled [2]. A prototype of novel social software fulfilling part of the elicited requirements is described in Section VII. A scenario for integrating these new paradigms in engineering education is drawn in Section VIII before concluding in Section IX.

II. User-centered Perspective

The current practice in higher education for faculty members struggling to increase their h-index [3] (or any other fashionable academic metrics) is to concentrate on lectures and a few office hours. Lecturing is the most effective approach from an administrative (well recognized duty) and teaching (best return on effort ratio) point of view. However, its impact on students' learning (knowledge and competences acquisition and consolidation) is rather limited. As a consequence, most of students' learning activities occur through personal work; partially with the help of teaching assistants. In the last 2 decades, technologies were introduced mainly to extend the classroom reach. Nowadays, some lectures are podcasted as example in *iTunes U* and *PowerPoint*-like presentations are made available on institutional LMS. In the latter, the students can also post their homework assignments without heavy involvement of teachers or institutional staff. Additional interaction occurs between students and educators through email and course-related blogs. Recently, in a move to develop the acquisition of high-level skills and competences, more active learning opportunities like labwork or teamwork have been introduced and are supported by relevant technologies, which are also often integrated in LMS. Due to the lack of adequate institutional resources, the support for such activities – which are highly demanding in terms of coaching – is unfortunately not always sufficient.

To compensate for their increasing isolation [4] and the standardization of the resources, which result from the presence of LMS or just from the lack of sufficient face-to-face interaction with educators, the students are relying more and more on peers and technology of their choice to manage and complete their learning activities in a self-directed manner. As pointed out by Attwell [1], *Google* is the most used e-learning platform in such a context where students are struggling to find relevant and personalized resources [5] and support.

This trend is counterproductive for both the institutions and the learners. The institutions are undermining their reputation and their attractiveness by losing the control on the resources and their usage. The learners, especially the ones with little social network and limited digital literacy, waste their time in unproductive search rather than focusing on productive activities.

Fortunately and thanks to the spreading of social software platforms and open learning repositories, there is currently an opportunity for institutions and learners to establish a stimulating and constructive interaction to strengthen learning and increase effectiveness. The idea is not for the institutions to invade the social space of the learners, but rather to promote trusty resources and academic presence that can be integrated by the learners themselves in their own spaces and own communities [6].

There are several challenges associated with such a move. First, the social spaces of the students have to be better understood, especially their relations with informal or self-directed learning [7]. Second, one has to evaluate how engineering education resources can be integrated in such spaces without destroying their unique personal and social nature. In other words, could those personal environments be turned into personal learning environments [8]? Third, all the necessary features to turn personal environments into personal learning ones have to be elicited, taking into account the necessary bridges to link the digital Web 2.0 realm and the physical world that coexist when blending formal and informal education. Finally, the roles the educators and the institutions have to play with respect to this evolution have to be reconsidered carefully. This paper focuses on the third issue, which is discussed in the next sections.

III. PERSONAL LEARNING ENVIRONMENTS

Personal Learning Environments (PLE) are not monolithic systems. They can be simply a set of devices, tools, applications, and physical or virtual spaces associated by learners at a specific time, for a specific purpose, and in a given context. A student's desk covered by books and notes, combined with a computer holding a collection of slides and documents with the associated applications for reading and editing, integrating a browser to access the Web or just the institutional LMS, is already a PLE. Such PLE, even though effective, is yet to reap potential benefits of customization and collaboration offered by Web 2.0 technologies. In this paper, we focus especially on the exploration and exploitation of new Web 2.0 features that strengthen the role of the social repositories and communities in self-directed learning, enabling learners to assemble and customize even more effective PLEs. As a consequence, end-user Web 2.0 services, online social spaces and shared applications are especially investigated, with a special focus on platforms where they can be aggregated, integrated, or mashed up.

Approaches and standards for the aggregation and the integration of Web 2.0 components as PLE services bundles have been investigated with an emphasis on interoperability issues [9]. Mashup platforms like *iGoogle* (www.google.com) or *Netvibes* (www.netvibes.com) also show a high potential to be exploited as Web 2.0 PLEs. In such framework, Web 2.0 components or services bundled together are often widgets or similar Web artifacts.

As the integration of PLEs relies on tools, artifacts and people collected or invited by users from the whole Webosphere, trust in the quality of the resources, the security of the distributed information storage (especially for personal and competence-related information) and the reputation of the providers or the communities are instrumental in enabling the self-directed repurposing of Web 2.0 spaces and services for learning.

IV. REQUIREMENTS ANALYSIS APPROACHES AND HYPOTHESES

The design and deployment of Web 2.0 PLEs is a completely new design paradigm for three reasons. First, PLEs are not end products; they are rather contexts or spaces continuously crafted and personalized by individuals according to their goals, interests, activities and even mood. They are not controlled by designers, service providers, or Web masters, but by end users. The role of third parties is somehow limited to providing users with convenient integration and customization solutions. Second, the design and integration processes themselves as well as the appropriation of the PLEs are part of the underlying social or learning activities. In this perspective, design and integration cannot be decoupled from socializing, interaction or learning. Third, PLEs are not just collection of artifacts; they can also integrate individuals, groups and communities that impact their nature, features, and evolving structure. Finally, one should underline that PLEs are not unique, even for a given individual. People continuously move from one PLE to another when migrating to different learning contexts. The continuity of the activities, especially the learning activities, has to be ensured and sustained not only within a PLE, but also across PLEs if learners wish to do so. Conversely, learners may also want to keep a clear separation between some of their PLEs and the associated groups or communities. This vision of the exploitation of Web-based mashed-up PLEs in a personal learning framework constitutes the underlying hypotheses for requirements elicitation as presented in the next section.

In the ROLE European project mentioned in Section I, a multidimensional approach has been implemented to elicit the functional and non-functional requirements of personal learning environments. A range of conventional as well as emergent methods and tools for capturing and analyzing requirements have been deployed, including Web-based focus groups (testbed-oriented, longitudinal studies), workshops, questionnaires, interviews, and online communities of practice (CoP). Specifically, focus groups and CoP are consistent with the principles of participatory design, which is underpinned by the philosophy of user-centered design. Furthermore, CoP aligns with the emerging social requirements engineering approach [10][11]. Whilst the requirements engineering process in ROLE is ongoing, some interesting findings could already be derived from two workshops conducted and will be elaborated subsequently.

V. Requirements Analysis: Preliminary Findings

Instead of carrying out long ethnographical field studies with learners, a hybrid strategy employing both top-down (e.g., expert reviews) and bottom-up approaches (i.e., end-user focus groups) has been adopted. The intention is to actively involve all stakeholders during the entire design and development process. Scientific discourses among experienced researchers and practitioners in the field of technology enhanced learning (TEL) have been conducted through workshops and interviews. One of the workshops was held in May 2009 in which 26 ROLE project partners were involved to share their ideas and visions about responsive open learning environments. The academic backgrounds of the workshop participants were heterogeneous, including engineering, computer science, mathematics, education, psychology, management, etc. Most of them were experienced in interdisciplinary collaborations in the context of TEL. In the workshop, a series of short presentations outlining the main concepts of respective visions were followed by small group discussions where participants were asked to complete a template to describe pedagogical and technical approaches that were deemed essential for responsive open learning environments and to derive requirements from the descriptions.

The workshop materials were analyzed. Interestingly enough, during the presentations and discussions, the term personal learning environment was employed so frequently that it almost became synonymous with responsive open learning environment. However, strictly speaking, there are nuances between these two closely related notions. Here we do not delve into deeper discussion on this issue, but draw on the outcomes of the workshop that has incidentally set its focus on PLEs. The range of approaches and issues addressed during the workshop was diverse. Most commonly mentioned pedagogical and technical concepts for personal learning environments are depicted in Figure 1 and Figure 2 in the form of tag clouds, respectively. Considering the scope of the paper, we discuss only those that are highlighted in both figures.

The most important pedagogical aspect pointed out by the workshop participants is the integration of PLEs in a self-directed or self-regulated (the subtle differences between these two terms are out of the scope of this paper) learning framework where the communities play a critical role, as illustrated by the terms 'community-based', 'collaborative' and 'social'. The term 'activity-based learning' covers both individual and collaborative aspects of learning activities. Closely associated with the key concern of self-regulated learning is motivation. The term 'adaptive' has instigated interesting discussions about user-driven vs. system-driven recommendation.

The most important technical aspect pointed out by the experts is the usability of PLE widgets in a free integration framework. Not surprisingly, 'Web 2.0' and the associated concept of 'collective intelligence' are among the frequently mentioned technical terms. Open standards such as OpenSocial and XMPP (Extensible Messaging and Presence Protocol) were addressed alongside with the discussion about semantic interoperability. The term "cockpit" is used metaphorically to refer to the typical graphical user interface template of mash up platforms.

Figure 1. Tag cloud of pedagogical approaches relevant to PLE deployment.

Figure 2. Tag cloud of technical approaches relevant to PLE deployment.

Some interesting discussions also occurred regarding the necessity and the way to integrate learning paths or sequences of activities (as considered in pedagogical design) in a self-directed learning and PLE framework. No consensus emerged on this issue. However, this discussion led to a clear implication that PLEs are not persistent environments. They should evolve according to the learner's objectives and achievements, as well as competence management requirements.

In a follow-up workshop held in July 2009, twelve PLE and technology enhanced learning experts from all around the world external to the ROLE project helped to better specify key PLE features by contributing to the requirements elicitation and refinement process. They, together with 21 ROLE project partners, discussed in detail the two key concepts: *responsiveness* and *openness*. Specifically, the notion of PLE responsiveness was defined as "the ability of the learner to successfully configure the learning environment based on recommendations, adaptations and personalization". As adaptive learning systems strongly rely on centralized user models and learning styles, it appears that system-driven adaptive features should not be a priority in PLEs. It could even be counter productive to their success by giving the impression to the learners that they lose control. As a conclusion, a stronger focus on user-driven recommendation and personalization (preferences) should be considered.

Results from analyzing the data collected in the aforementioned two workshops corroborate the assumption about the need to enrich or even replace monolithic learning environments with a highly flexible, responsive and customizable environment according to the needs of the learner. The data analysis has also led to the initial set of pedagogical and technological requirements for the ROLE project. Pedagogically, it is important to incorporate design decisions around the concepts of self-regulated learning [12] with the intention to foster communities of practices. However, the range of learning tools, content, communities and services on the Web are so huge that it could become an overwhelmingly challenging task for a learner to decide what to use when, how and why. Hence, ROLE aims to provide learners with support for building a personal learning environment and learning with it in a pedagogically meaningful way. One way currently considered by ROLE is to provide users with pre-built PLE templates accompanied with screencasts showing how and why the templates can be assembled. Traditionally, learners within formal educational environment are used to instructor-led, organisational monolithic learning environments. Over the years, this didactic approach has given way to a more constructive self-regulated learning approach to facilitate life long learning. Technologically, an architecture and interoperability framework enabling the composition and federation of different learning services is required. An approach to integrating services, tools, and data relevant for a learner is deemed necessary as well.

Of particular importance is the notion of *usability*, which was regarded by most of the workshop participants as a very significant quality attribute for the integrated learning services and other outcomes of ROLE. Specifically, a comment from one of the PLE experts highlights the concern*:"…. even if you can solve the deliverability problems it would be great but some people can't deal with a PLE, how do they construct it….".* However, a usability study performed by Silva and Dix [13] indicates that the popular social networking website *YouTube* has some major usability issues despite its popularity. Paradoxically, user satisfaction is nevertheless acceptably high; it thus raises a question on the necessity of rigorous usability. This claim is confronted with an counterargument put forward by Rigutti and Paoletti [14] who suggest that users might overlook the usability factor when a technology is new, satisfies their needs and there are no competing products. However, as the technology matures and more products are developed, products that are highly usable will sustain. Through ROLE we are attempting to deliver a novel approach wherein learners will be able to assemble their own PLEs. As this is a new approach to learning in a more de-centralized form, the uptake of such an approach at an early stage is critical.

Through the different requirements capturing activities mentioned above, a set of testbed-specific and some general use cases have been documented. Consequently, about 50 functional and 15 non-functional requirements (e.g. usability, privacy, trust, security) have been identified. The functional requirements are sub-divided into three groups in terms of service types: learning domain/planning (e.g. assessment, tracking), core (e.g. authentication, authorization), and communication/collaboration (e.g. chat, calendaring). It is imperative to prioritize these requirements, thereby enabling the development teams to manage their tasks efficiently and effectively. We have adapted the Kano analysis approach [15]. Accordingly, requirements should be prioritized with regard to user satisfaction – a quality dimension that is upheld in the ROLE project. With the simplified analysis scheme, we have categorized each requirement with one of two values – "must have" and "recommended". As requirements capture, analysis and validation will be a continuous process throughout the project's lifetime, the preliminary findings reported above will be subject to further refinement.

VI. PARTICIPATORY DESIGN

Concurrently with the conversations between experts, five testbeds of complementary nature have been selected to elicit requirements at transitions between various learning settings. In these testbeds, a participatory design approach [16] is implemented under the collaboration of testbed coordinators, learner representatives, educational experts, and potential services providers to offer prototypes of PLE service bundles that could fulfill learners' expectations and strengthen their current practices. It has been demonstrated in previous similar initiatives that a proper selection of the stakeholders for the participatory design implementation is essential [17]. Especially, user and service mediators with similar decision power have to be selected to enable balanced negotiation of meaning [18] and construction of usefulness [19] regarding the requested services by the users or proposed services by the development teams. This process is also instrumental for the appropriation and the organic spreading of the solutions on the Webosphere.

Three testbeds related to higher education are discussed below. The two other testbeds are related to professional learning and are consequently outside the scope of this paper. One should however mention that a clear requirement of one of the two omitted testbeds is the necessity to make the LMS interoperable with the upcoming PLEs to enable a smooth transition between proprietary and open environments or contexts.

The first testbed deals with the use of a Web 2.0 *Knowledge Map* in a course on programming techniques at the RWTH Aachen University. The main objective is to couple the *Knowledge Map* service with a message board within a PLE in order to enable contextual discussions and map auditing between students and alumni working in software companies. This approach should bring added value to the course in terms of motivation, content and interaction. It should also ease the transition of students between the academic and the professional world.

The second testbed deals with second-language learning in a multicultural framework and in a continuing education context at the Shanghai Jiao Tong University (SJTU). The main objective is to enable live discussions with native speakers and personal practice at transition between jobs, thanks to the integration in the PLE of tools that can exchange data, such as online dictionaries, pronunciation, micro-blogging, videoconferencing, and multimedia discussion tools. In a political context where social sites are often blocked, a PLE in which services can easily be replaced by equivalent non-blocked ones is essential. The integration with mobile phones is also important as part of the activities is carried out at distance. The current PLE instantiation shown in Figure 3 is implemented using *Liferay* Portal Community Edition, (www.liferay.com).

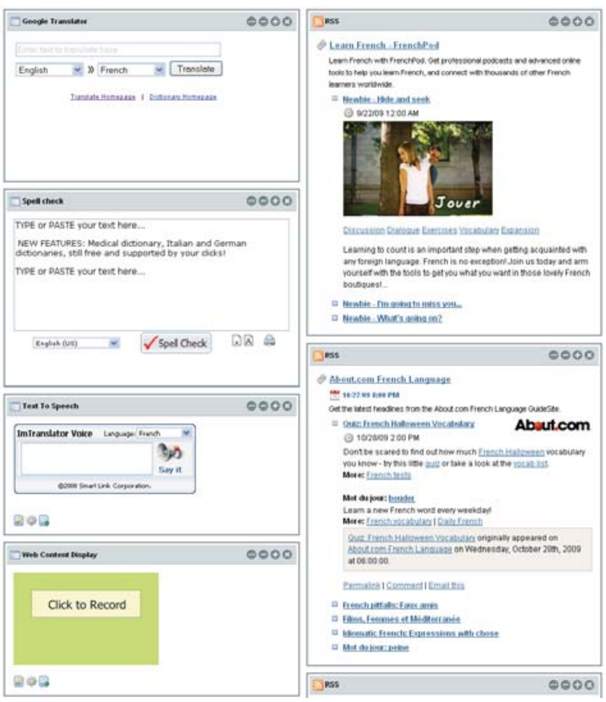

Figure 3. Screenshot of the PLE used in a French as a second language class at the Shanghai Jiao Tong University (courtesy of C. Ullrich, SJTU).

The third testbed deals with the exploitation of the OpenLearn learning space offered by the UK Open University for users in transition between informal and formal learning. Its objective is to progressively switch from a course-centric to a student-centric structure to better fulfill the users' repurposing needs, and to boost open content delivery technologies. It also aims at enabling any online learner to get support from a community of learners with similar backgrounds and goals. As it already targets educators and institutions, it is an interesting testbed to investigate the similarities between the educators' and the learners' integration approaches to combining resources in PLEs for sharing purposes or for personal usage.

Due to the heterogeneity of the testbed end users and the fact that they are geographically widely distributed; it is deemed cost-effective to facilitate the focus group discussions using a Web-based environment. The open source *elgg* (http://elgg.org) based social networking environment was selected as it offers all the basic Web 2.0 tools (blogs, wikis, discussion forums, social bookmarking, micro-blogging, etc) in a widget-based environment (Figure 4).

This widget-based environment enables the users to visualize what ROLE aims to achieve beyond the feature sets of similar systems currently available. It is expected that with each personal learning services bundle release, the focus groups will provide feedback on various aspects of the respective prototypes, thereby enabling us to collect evaluation data and identify potential issues that may result in refined requirements. Currently, the active focus groups are all end-user-oriented. These end-users (students, life-long learners) participating in the focus groups actively use the current learning environment provided by the test-bed institutions. The test-bed leaders have recruited the participants with the aim to provide a fairly representative sample. However, we plan to convene an expert-oriented focus group at a later stage when required. The rationale for putting together an expert-oriented focus group (internal as well as external) is to negotiate unresolved issues identified through other methods and to validate outcomes and findings from a top-down point of view.

Interestingly, the most requested features in the three described testbeds are a collaborative recommendation system proposing knowledgeable and trustful peers to interact with, and an integrated service for live interaction with them (such as *Skype* or *FlashMeeting*: http://flashmeeting.open.ac.uk). Knowledge mapping solution is also mentioned twice, maybe as an emerging Swiss knife of the knowledge worker dealing with information, ideas and competences (gap) management challenges. This low number of requested tools confirms previous finding [20] showing that typically a couple of services are used simultaneously and should be able to communicate synchronously for actual learning activities. This is coherent with the physical dimensional constraints of computer displays or Web browser windows when switching too often between contexts has to be avoided for minimizing cognitive overload. Communication with other services used at other stages in the learning process can rely on asynchronous data exchange. The XMPP protocol (http://xmpp.org) seems a promising solution for enabling communication and interoperability in the PLE framework. Various recommendation models and techniques are currently investigated in the ROLE project, including contextual collaborative solutions relying on users' weighted trust network. They will be reported in further publications.

To summarize, designing PLEs nowadays does not consist in developing one additional learning management system or

Web 2.0 social software applications, but it rather concentrates on providing the underlying infrastructure and recommendation solutions that rely on proper trust and reputation models mapped to the continuously evolving social and institutional contexts. Such solutions should enable users to aggregate in their own environments empowering technologies, communities, learning resources, activities and Web tools. The contextualization and repurposing of the aggregated environments for learning should be enabled according to implicit or explicit learning strategies or goals. The recommendation should be self-directed by unobtrusively involving the learner in the process, and by taking into account his/her learning contexts and interests, as well as his/her network of trusties.

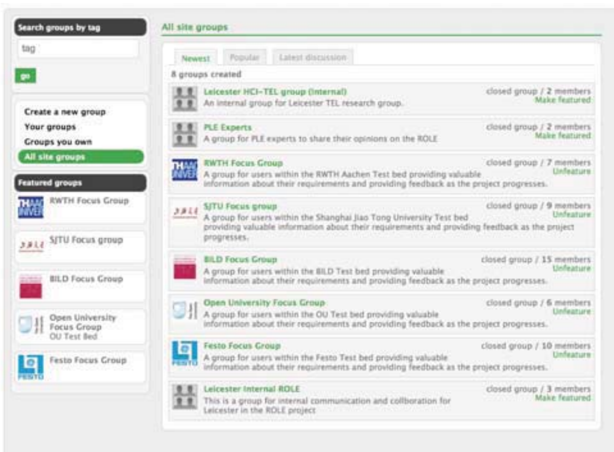

Figure 4. Web 2.0 based Focus Group facilitation.

VII. GRAAASP SOCIAL SOFTWARE PROTOTYPE

Successful Web 2.0 solutions result from a deconstruction-reconstruction process of the traditional collaborative learning practices and artifacts in order to extract essential features; followed by the implementation of a proper participatory design approach.

A previous attempt to develop and exploit a social software platform called *eLogbook* as a knowledge management platform in communities of practice and as a collaborative learning environment for engineering education gave good results in terms of integration of services (such as simulation and remote experimentation applets), but did not spread as expected outside the Swiss Federal Institute of Technology in Lausanne (EPFL) where it was developed due to usability reasons [21]. Specifically, it did not meet the requirements elicited in the previous section in terms of recommendation and relation with people. Only internal resources and registered members were accessible through a search feature. Invitation of external people was possible but required too much configuration and acceptation steps to be completed quickly. Also, most users did not understand its innovative graphical user interface (GUI) metaphor. As a matter of fact, this partial failure shows a pitfall associated with the participatory design approach that was implemented to design *eLogbook* in the framework of the Palette European Project (http://palette.ercim.org). The negotiation between the user and the developer mediators ended up with too many features that were integrated detrimentally to the GUI tuning. This problem can be avoided by pushing further the Web 2.0 philosophy of developing only wrappers to integrate as much as possible existing services or widgets in PLEs.

The *Graaasp* social software introduced in this section is an evolution of *eLogbook* hopefully correcting the flaws of the latter and that can be described as a Web 2.0 contextual aggregator. *Graaasp* is built on the 3A interaction model [22] that is particularly focused on describing and designing social and collaborative environments. The presence of three “a”s in *Graaasp* name is a reminder of this underlying model.

The 3A model accounts for three main constructs or entities: **Actors** are entities capable of initiating an event in a collaborative environment. They can be humans as well as virtual agents. Actors create collaboration spaces where they conduct **Group Activities** to reach specific objectives. In each of these activities, actors can take different roles, each of which consisting of a label and an associated set of rights. Furthermore, actors produce, edit, share and annotate **Assets** in order to meet activities objectives. Assets can consist of simple text files, RSS feeds, wikis, videos or audio files. The model accounts for Web 2.0 features: entities can be tagged, shared, commented, linked together and rated. As an aggregator of 3A entities, *Graaasp* can serve not only as a networking platform, a repository of assets and an activity management system, but also as a mounting space bringing together content and services from other Web 2.0 applications and social platforms.

While keeping the 3A model internally, *Graaasp* displays separately in its GUI physical and virtual actors, which are labeled as People and Tools, respectively. The main characteristic of the *Graaasp* GUI is its ability to enforce contextual aggregation of its four categories of entity, i.e. **People**, **Spaces** (group activities), **Assets** and **Tools** (widgets, applets). Any entity dragged and dropped in the main area (❶) becomes the current context of aggregation and interaction (Figure 5). The content of the associated columns (❷, ❸, ❹ and ❺) is automatically updated to only display entities with direct links to the chosen context. Direct links are relations explicitly made by users. New links with the current context can be created simply by dragging and dropping new entities on top of its dedicated grey banner area (Drop here to link). The new entities can be preselected favorites (❼) or entities kept in the clipboard (❽). They can also result from a search or be recommended by the systems according to user preferences (❻ or ❾). The recommendation takes into account all the direct and indirect links existing between *Graaasp* entities the user has access to and the current context. Indirect links can be common tags or links going through other entities (like two actors using the same tool or having collected the same asset in a space they belong to).

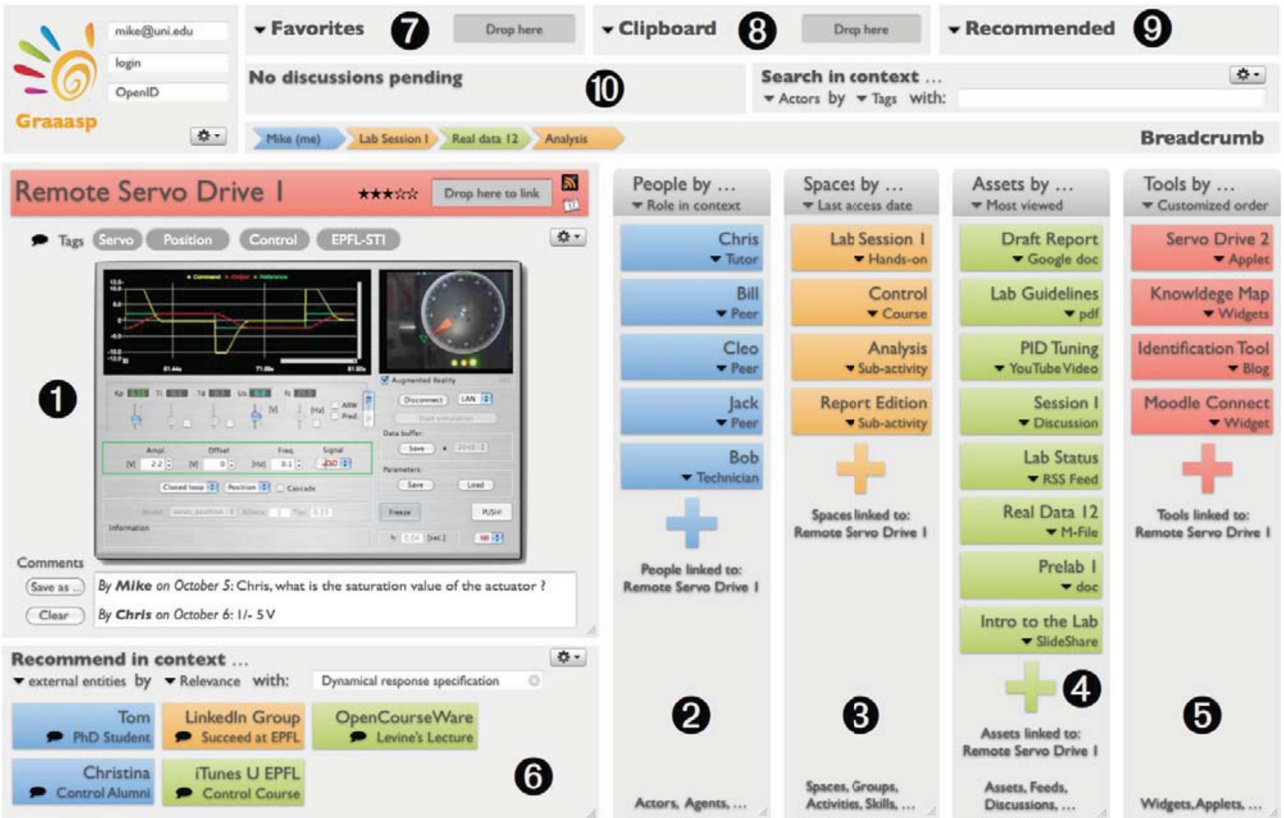

Figure 5. Recent Mock-up of the *Graaasp* social software (the current prototype is accessible at http://graaasp.epfl.ch).

The breadcrumb area displays the recent entities successively selected as context. The content of the columns can be displayed in predefined order (creation or last access dates, names, roles, so on and so forth) or in a customized order that can reflect the relative importance of the entities in the given context. Each category of entity supports different types that have different properties. For example, an asset can display the postings corresponding to a RSS feed, while another asset can just contain a static document.

Grabbing the nature and the implication of the various existing types of links may be challenging for users. However, the graphical representation should help in visualizing the existing relationships and in exploiting the contextual navigation. Hence, *Graaasp* uses pre-defined settings to translate drag-and-drop actions into meaningful relations. As an example, if a blue rectangle representing a person is dropped onto a space selected as current context, this person is invited to join this space as member with the relevant rights (this member role can later be modified). If a green rectangle representing an asset is dropped onto a person selected as current context, this asset is shared between the user and that person. The implications of the different drag-and-drop actions are currently adjusted and validated with volunteers.

The *Graaasp* internal recommendation engine will show its full potential in 2010 when resources for other social platforms will be mounted as external 3A entities. Currently, specific external resources can already be imported into *Graaasp*. As example, a *YouTube* video or a *SlideShare* presentation can be imported into *Graaasp* as an asset just by clicking on the Graaasp it! bookmarklet. A bookmarklet is an applet stored as the URL of a bookmark in a Web browser that can be executed at anytime when visiting supported websites to import interesting resources in *Graaasp*. Plug-ins to support additional websites can easily be implemented on the *Graaasp* server side, broadening in such a way the scope of the bookmarklet without the need to reinstall it every time improvements are made.

It is not clear yet whether users will indeed adopt *Graaasp* as a PLE. Further validation with educators and learners should be conducted. However, its design clearly supports the contextual aggregation of resources, including widgets in the tool category, and communities for general knowledge management or learning purposes. In that sense, it can be seen as a PLE generator that could be used by educators to prepare and propose potentially useful learning service bundles to their students. These bundles can be exploited directly in *Graaasp* or possibly exported in the future to other platforms. In such a way, the experience and the educators' accredited resources and networks can be embedded in shared PLE configurations that can include a predefined set of tools to be possibly exploited by the students. Hence, the burden for the students to build from scratch their PLEs may be reduced. These configurations can also integrate recommended experts using *OpenSocial* [23] technology.

VIII. Exploitation Scenario in Engineering Education

As a tentative exploitation scenario of the *Graaasp* social software as PLE in engineering education, one can consider the example of a student carrying out collaborative laboratory activities in control (a mandatory course offered at EPFL to students in mechanical, electrical, and micro engineering).

The students have three hands-on laboratory modules to complete during the last semester of their bachelor program. They can access the laboratory experiments directly on campus once a week, or remotely, 24 hours a day, 7 days a week. The typical laboratory setup introduced to practice position and speed control is a servo drive. An applet is available for local or remote data acquisition and control of this system [24].

Mike, a student in electrical engineering was already using *Graaasp* to manage the EPFL Jazz band. He decided to use the same social software to manage the control laboratory modules with peers. As EPFL strongly support the development of autonomy and teamwork skills, he knew that he could freely choose the other students he wished to work with. After a discussion at the cafeteria, Cleo, Bill and him decided to carry out the lab together. They had complementary competences and had already collaborated effectively in other contexts.

Mike connected first to *Graaasp* to create a new space called Lab Session 1 in order to support the lab activities associated with the first module to complete. He then invited Cleo and Bill to join this activity as peers. He also searched for available servo drives and linked the applet corresponding to the Remote Servo Drive 1 as tool in his Lab Session 1 space. He later picked Chris as tutor as he had got good feedback on his competences from Jack, a member of the Jazz band and master student in mechanical engineering who took the same lab session the previous year. Mike decided to invite Jack in the space, just in case further interaction with him would be required. Chris accepted the invitation to coach Mike's team, as he had not yet reached his quota of students. As a tutor, Chris is not in charge of the team evaluation in order not to refrain them from discussing the subject matter openly. Mike also added tools and assets useful for the lab in the space, including his favorite Knowledge Map widget, a nice *YouTube* video showing how to tune the PID controller they have to work with, and the RSS feed which is updated with the current status of the actual lab experiments, just to be notified in case their selected servo drive will be unplugged for maintenance. He also created a *Google* doc for the collaborative editing of the report and shared it within the main space (Lab Session 1) and its corresponding sub-activity space.

When Mike started his first real experiment by dropping the Remote Servo Drive 1 applet as context, Bob, the technician in charge of the maintenance appears automatically as linked person. Also, three additional tools linked directly and publically to the applet by Bob became visible. An additional servo drive that can be used as backup, an Identification Tool for the processing of the measurements acquired on the servo drive and the Moodle Connect tool enabling the storage of the data for the users that are still using the old LMS of the university.

Mike got a list of additional relevant entities related to his context and with the additional keywords he gave, including the podcasts of the EPFL control course on *iTunes U* and the slides of a related MIT course available on *OpenCourseWare*, which gave him an additional perspective on the subject matter.

As Cleo was so happy to get all the material necessary to complete the lab assignments at a single but open place, and to be able to keep it even after the end of the course, she decided to continue to use and populate *Graaasp* for most of her other social and academic activities. Lately, she exported one of her space dedicated to Philosophy just by one click to *iGoogle*, a platform some of her friends preferred to use.

IX. Concluding Remarks

This paper discussed the motivations and the challenges associated with the introduction of personal learning environments in higher engineering education.

In addition to highlighting the need for a fundamental change necessary in the educational paradigm to better account and support personal learning, essential pedagogical and technological requirements pertaining to PLEs are pointed out. Some of the issues identified and highlighted in Figure 1 and 2 are still being discussed within ROLE's TEL community. These issues (mostly pertaining to self-regulated learning, community based learning, recommendation, inter-operability standards, PLE usability) are contentious in nature and will require diligent negotiation among stakeholders to reach an acceptable resolution. Especially, usability is elicited as one of the most challenging features of personal learning environments, together with the need of powerful recommendation capability to help learners find relevant resources and people in the Web 2.0 realm. Hence, the reader must bear in mind that ROLE is an ongoing project and this paper reports some of the issues that we have identified so far and presents a preliminary PLE prototype with potential resolutions for some of the open issues like recommendation or community cohesiveness.

An example of a novel Web 2.0 social software that can be exploited in engineering education is presented, together with an implementation scenario for laboratory activities associated with a control course. This example shows how both the pedagogical and the learning environment design can be adjusted for a better integration of formal and informal learning practices.

As an emerging topic in field of technology enhanced learning, the design and development of open and responsive PLEs is deemed challenging. A number of controversies entail further scientific discourses and more empirical validations. Amongst others, we name several examples: striving the balance between system-driven and user-driven personalization mechanisms (cf. the privacy issue pertinent to user profiling), deepening the understanding of trust-building enablers and integrating them into recommendation protocols, and identifying viable means to sustain the development of ever-augmenting widget-landscape. We aim to tackle these challenges in our future research work.

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Dr. Christophe Salzmann, Dr. Stéphane Sire, Ms Sandy El Helou and Mr Evgeny Bogdanov have contributed to the recent research and prototypes presented in this paper. The research work described in this paper is partially funded through the ROLE Integrated Project; part of the Seventh Framework Programme for Research and Technological Development (FP7) of the European Union in Information and Communication Technologies.

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Filling the gap of Information Security Management inside ITIL®: proposals for posgraduate students

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***Abstract*—This paper describes different proposals made at UNED, for post-graduated students, at the area of IT Services Management and specially trying to fill the gap, of paramount importance, of the treatment due in ITIL® (Information Technology Infrastructure Library) to Information Security Management. We analyze the treatment given to Information Security Management in ITIL, both versions 2 and 3, and describe the different at distance post-graduated courses we offer that fill these methodologies and discuss the opinions and evaluations of our students.**

Keyword: Information security management, ITIL, ISO 27001, Professional education.

I. Introduction

Every kind of organization is increasingly dependent of IT services to satisfy their corporative objectives and to cover their business needs [1] [2] [3]. This tendency provokes that IT (Information Technologies) Service Management is becoming an important factor for the success or failure of business in many organizations. A cause of the increase costs of IT services and low quality services is due to inadequate IT Services Management or does not work of desirable form [1].

But first of all, what is Service Management? Service Management is a set of specialized organizational capabilities for providing value to customers in the form of services. And, what is a Service? Service is a means of delivering value to customers by facilitating outcomes customers want to achieve without the ownership of specific costs and risks.

There are a number of widely applied standards and methodologies used for the alignment of Information Technologies (IT) departments with the business, inside each organization. One of the most relevant is called ITIL® (Information Technology Infrastructure Library) [4]. ITIL is the most widely accepted approach to IT service management in the world. ITIL provides a cohesive set of best practices, drawn from the public and private sectors internationally.

After this introduction of the context where we have done our research, the rest of the paper is organized as follows.

First, we do a small introduction to ITIL (Information Technology Infrastructure Library) both versions (2 and 3) and ISO 20000. In the next section we present the Security Management basis needed and its relation with ITIL. After that, this paper describes different proposals made at Electrical and Computer Department from UNED (Spanish University for Distance Education) [5], for post-graduated students, at the area of IT Services Management. Specially we try to fill this knowledge gap, of paramount importance, of security treatment due in ITIL. We explain the characteristics of these topics at distance courses, and how we try to stimulate the acquisition of practical knowledge by the students, promoting the practical work as a significant part of their works for the course.

Finally, we show the students evaluation of the last three years for these two courses that really encourages us to refine the courses and follow in the same direction.

II. ITIL® Version 2

ITIL (Information Technology Infrastructure Library), nowadays the most widely accepted IT service management framework in the world. ITIL arose in the '80s developed by the Office of Commerce of the British Government (Office of Government Commerce - OGC UK), [2] [3]. It provides a set of best practices detailed description, grouped in books, offering an extensive list of roles, threats, procedures and responsibilities that can be adapted to almost any kind of IT organization. The enormous amount of topics that those publications cover makes ITIL a reference, more essential day by day, to establish new improvement goals inside an IT organization.

ITIL Version 2 (which appeared at the end of the '90s) has two big modules as you can see in Fig. 1: Service Support and Service Delivery.

The other four ITIL version 2 core books (Planning to Implement Service Management, The Business Perspective, ICT Infrastructure Management and Application Management) are out of our research, because they do not have processes so they have not the same importance than Service Support and Service Delivery have.

Fig.1. ITIL version 2 core books (OGC source).

Inside Service Support book we can find the following six parts (which are five processes and a function): Incident Management, Problem Management, Configuration Management, Change Management, Release Management and a very important function: Service Desk.

Inside Service Delivery we can find also six parts (which are processes too): Service Level Management, IT Financial Management for IT Service, Capability Management, Availability Management, IT Service Continuity Management and Security Management.

ITIL processes all together are shown in Fig. 2, on the right you can see Service Support processes and on the left you can see Service Delivery ones:

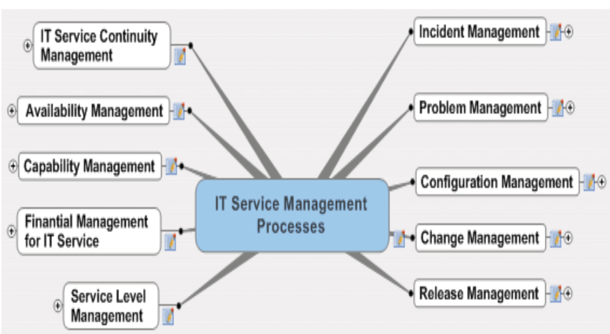

Fig.2. IT Service Management Processes (own source)

Service Support area describes how customers can access the appropriate services in order to assist to their business. Service Delivery area describes the services offered to the customer and what is required to provide those services.

III. ITIL® VERSION 3

Many public and private organizations worldwide implement these best practices following the version 2 of ITIL but since two years ago there is a new version that it is being implemented also, but in a much slower pace.

ITIL Version 3 [6] (also known as ITIL Refresh) took off two years ago and it has some big changes related to previous version. This new version is focused on the service lifecycle.

ITIL version 2 has undergone a major refresh which is version 3. Version 3 represents an important evolutionary step in its life. The refresh has transformed the guidance from providing a great service to being the most innovative and best in class. At the same time, the interface between old and new approaches is seamless so that users do not have to reinvent the wheel when adopting it. Version 3 allows users to build on the successes of version 2 but take IT service management even further.

Now there are only five core publications which describe the key principles of IT service management and provide a high-level overview (Service Design, Service Operation, Service Strategy, Service Transition and Continual Service Improvement).

Fig.3. ITIL version 3 core books (OGC source).

IV. ISO 20000

On the other hand, on 15th December 2005 ISO (International Standard Organization) [7] adapted BS 15000 British norm (based on ITIL and developed to officially define effective service delivery requirements for the business and their clients) into a new international standard: ISO/IEC 20000.

Although ISO 20000 does not formally include ITIL exposition, it does describe a set of management processes aligned and complementary to what ITIL defines.

ITIL provides guidance on what should be done in order to offer users adequate IT Services to support their business processes. ITIL certifications are available for individuals but until recently there was no way for an IT organization to prove that it is working along the ITIL recommendations. The ISO 20000 standard was conceived to fill this gap. Initiated by the two organizations itSMF (IT Service

Management Forum) [8] and BSI (British Standard Institute), it is modeled upon the principles of ITIL and for the first time offers IT organizations the possibility to have their IT Service Management certified.

Actually it is considered that each ITIL book offers deeper information and a best practices guide about subjects located in the scope of ISO 20000 norm. In contrast to the ITIL books, ISO 20000 does not offer specific advice on how to design your processes. It is rather a set of requirements which must be met in order to qualify for ISO 20000 certification.

The great implantation on private and public sector companies and the need of organizations to demonstrate their work this way by means of ISO 20000 certification, is causing a great demand of professionals on this field.

V. SECURITY MANAGEMENT

Information Security describes activities that relate to the protection of information and information infrastructure assets against the risks of loss, misuse, disclosure or damage. Information Security Management (ISM) describes controls that an organization needs to implement to ensure that it is sensibly managing these risks.

The risks to these assets can be calculated by analysis of the following issues:

- Threats to your assets. These are unwanted events that could cause the deliberate or accidental loss, damage or misuse of the assets.

- Vulnerabilities. How susceptible your assets are to attack.

- Impact. Is the magnitude of the potential loss or the seriousness of an event.

Standards that are available to assist organizations implement the appropriate programmes and controls to mitigate these risks are for example ISO 27001, ITIL and COBIT.

We consider that ISM has crucial importance because almost every company (even smallest ones) does their job using networks into their organization to exchange internal information, and uses Internet too. Each day is more necessary to deal with possible security problems on a global way, considering external threats from Internet but also internal treats. Information Security aspects are really important for company success and business stability.

VI. ITIL AND SECURITY MANAGEMENT

It is a proven fact that ITIL version 2 has a great weakness on Security matters. Between the existing set of Service Delivery books, there is a small one, called Security Management, that shows on a very light way what to do with security, and there is no later reference about this point in any other book of this version. Because of this weakness, organizations that implemented ITIL version 2 since years ago have had to fill this gap by their one, using other kind of approaches. That is the reason why Security Management process does not even appear in Fig. 1.

Nevertheless, on ITIL version 3, concretely in Service Design book, we can find much more information about what to do with Security Management. Although this new version touches Security on a deeper way, there are lots of links in the mentioned book to ISO 27001, which is the world wide extended standard followed on security subject.

Therefore, ITIL version 3 gives a much adequate treatment [9] to security that ITIL version 2 does, identifying the details of the structure and implementation of the Information Security Management process with the good practices for implementing an ISM System (ISMS) included in the ISO 2700x family of standards.

ISM needs to be considered within the overall corporate governance framework. Corporate governance is the set of responsibilities and practices exercised by the board and executive management with the goal of providing strategic direction, ensuring that the objectives are achieved, ascertaining that the risks are being managed appropriately, and verifying that the enterprise resources are used effectively.

The purpose of the ISM process is to align IT security with business security and ensure that information security is effectively managed in all service and Service Management activities.

An information security management system (ISMS) is, as the name implies, a set of policies concerned with information security management. The idiom arises primarily out of ISO/IEC 27001.

The key concept of ISMS is for an organization to design, implement and maintain a coherent suite of processes and systems for effectively managing information accessibility, thus ensuring the confidentiality, integrity and availability of information assets and minimizing information security risks.

As with all management processes, an ISMS must remain effective and efficient in the long term, adapting to changes in the internal organization and external environment. ISO/IEC 27001 therefore this incorporates the typical "Plan-Do-Check-Act" (PDCA) Deming approach to continuous improvement:

- The Plan phase is about designing the ISMS, assessing information security risks and selecting appropriate controls.

- The Do phase involves implementing and operating the controls.

- The Check phase objective is to review and evaluate the performance (efficiency and effectiveness) of the ISMS.

- In the Act phase, changes are made where necessary to bring the ISMS back to peak performance.

The best known ISMS is described in ISO/IEC 27001 and ISO/IEC 27002 and related standards published jointly by ISO and IEC.

Another competing ISMS is Information Security Forum Standard of Good Practice (SOGP) [10]. It is more best practice-based as it comes from ISF's industry experiences.

VII. The Computing Engineering Students Problem

On the other hand, Spanish students on Computing Engineering, when they finish their degrees, have little or no idea on Security Management and surely no idea at all about ITIL. If we are talking about the huge importance of ITIL all over the world, as the most accepted approach to IT service management, how is this possible?

We face a situation in which students that finish the Computing Engineering careers, at least in Spain, don't know all these kind of standards and methodologies and don't have a practical, day to day, approach to implement and maintain a good information security policy within an organization.

It is well known that the alignment of Information Technologies (IT) departments with the business is essential, and ITIL best practices are probably the best solution. That is the reason why from UNED we are trying to fill this gap in students knowledge, because at the moment we really believe this is a weakness. So, we are teaching post-graduated students to be experts on these topics, both Security Management and ITIL, just to be ready for the real world.

VIII. The UNED Solution

As everybody knows, UNED has distance students almost all over the world, so the way we teach is a little peculiar. We normally never met our students, therefore, teacher-student communication has everything to do with new technologies platforms, Internet and so on.

Our guidance and attention to students is made using computing and telecommunications, utilizing email on Internet or Learning Management Systems and, when this kind of communication is not possible, we attend them by telephone, post mail or fax.

Our attention is personalized, proper of a high quality education, which is a feature common in all UNED actions. Most part of material is given to students at the beginning of the course, so they can plan their study rhythm. Sometimes, when necessary, we make presence sessions using videoconference.

In addition to all this, during the courses we propose students to do a end of course personal work, that we correct, inform and send back to them, so they are able to evaluate themselves and improve their knowledge.

Due to all the reasons explained before, and trying to take advantage of the professional practice of some of the authors, from Electrical and Computer Department, four years ago we began to offer post-graduate at distance courses for helping students to understand all these matters.

At the moment we offer [11] two related courses:

1- Professional Expert in IT Services Management based on ITIL® and ISO/IEC 20000.

2- Professional Expert in Information Security for Computer Networks.

Professional Expert in IT Services Management based on ITIL® and ISO/IEC 20000 main goal is giving enough knowledge to students, so they can use a common language in service management based on ITIL. Also they get a very high level to face up ITIL foundations examination certification (1 hour multiple choice exam: basic understanding of the ten ITIL Service Delivery and Service Support processes and the Service Desk function).

Besides this, we try students understand tight relationship between ITIL and ISO 20000 and also students know different approach for new ITIL version 3. Each course is divided in four parts: introduction, 2 didactic units and the student's final work. The didactic units of this course (with three chapters in each unit) are the following:

1- IT Service Management and its implementation using ITIL best practices.
   a. Introduction to IT Service Management.
   b. Service Support Processes.
   c. Service Delivery Processes.

2- UNE/ISO 20000 standard and ITIL new version.
   a. ISO 20000 analysis and description.
   b. Life cycle new approach on ITIL version 3.
   c. Implementing ITIL version 3 practices.

Professional Expert in Information Security for Computer Networks main goal is giving to student completely updated technical knowledge on systems security and communications networks of computers. This course has two units (with three chapters in each unit):

1- Infrastructure security, systems security, organization security and biometrical systems.

a. Information Security at networks computer. Protocols at client/server communications.

b. Security Policy for company networks. Security attacks at network company classification.

c. Use of biometric techniques in security.

2- Cryptography and defense to attacks of security networks.

a. Introduction to Cryptography.

b. Modern Cryptography. Public and private keys Cryptosystems.

c. Non cryptographic defenses and cryptographic defenses at communication networks.

In our Information Security course first unit we also describe the goal and scope of Spanish laws which determine how to face the security problem of personal data files protection (LOPD, Spanish Law for Data Protection) [12] and also we describe security conditions on web servers (LSSICE, Spanish Law for Service Information Society and Electronic Commerce) [13]. More than 90% of our computer network traffic are TCP/IP [14] messages, so our students also study the comparison between stack IP and standard architecture OSI (Open Systems Interconnect) [15].

IX. Data and Tests Results

To keep in touch with the students real needs, we always make some exhaustive tests to our post-graduated students, to analyze if we are going in the right direction. And the results make us stand by.

As an example, these are some few questions and answers obtained during the last years:

1. To the question: Did you receive additional information about contents of your interest related with the course? Students respond yes: 91%.
2. To the question: Were your expectations about the course satisfied? Students respond yes: 86%.
3. To the question: Could you access to experts demonstration about application questions of the course? Students respond yes: 83%.
4. To the question: How do you value the course? Students respond yes: 86%.
5. To the question: Will you register in any other similar course? Students respond yes: 94%.
6. And finally, to the question: Will you recommend this course to anyone? Students respond yes: 92%.

In general, students' opinions should be very important at any university, but especially for us (teachers from UNED). We must know their opinions, checking that kind of feedback information, to be continually improving our methods and techniques to teach.

As we have explained above, we evaluate students with two kinds of tests. Firstly we evaluate them with at distance assessments for each unit that we correct and then we send the results and comments necessary to make students improve. And finally we evaluate students with a personal final work, which requirements are published at our web server. We are very proud of most of them. Examples of those final works are the following tittles:

- "Assessment of commercial and open source solutions for implementing Configuration Management Data Bases (CMDB): HP, Symantec, OneCMDB and ControlTier solutions"
- "Implementation of ITIL-based good practices to audio and video services"
- "ITIL and Prince2: Services Management and Projects Management"

This new academic year we are going also to give a new step in the ITIL course, trying to help the students to prepare the ITIL Foundations Certificate exam by having mobile evaluation tests on the main ITIL concepts. It will be as part of a European project, called mPSS (mobile Performance Support System for Vocational Education and Training).The students will have a number of simple tests, based on the ideas of well proven [15] DIPSEIL project for individualized high performance e-learning system, accessible from Internet via mobile devices, specifically mobile phones. The main idea is that the students can assess their knowledge of the main concepts related to ITIL and ISO 20000 at every moment and from anywhere and it will be part of several pilots related with the same high performance and individualized methodology, used also for another European Project, IPLECS (Internet-based Performance-centered Learning Environment for Curricula Support) that tries to build a complete European Engineering Master, completely accessible via mobile devices and for every European student.

X. Conclusions

In this paper we begin discussing what we think is a need to explain the differences in the approaches, of both versions of ITIL, to Information Security and the need for the graduate students to know, at least at a foundation level, these best practices approaches and standards.

With those two proposals from UNED, concretely from Electrical and Computer Department, we are trying to fill the gap we have just presented in this paper. We consider it is absolutely necessary students know all this methodologies, standards, laws ands concepts before they start working at any company in Spain or anywhere in the world.

Analyzing the results of the students' tests done at the end of each of our post-graduated courses, we conclude this is the path we have to follow to align students' knowledge and real world needs.

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Student Motivation and Cross-Curricular Development through e-Learning applied to Cooperation

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Abstract— **Technologies and especially information and communication technologies (ICT) are barrier breaking in the current social scenario. Their use is becoming essential for any professional, and their scope of use is becoming particularly widespread in education due to the existence of communication outside the classroom through e-learning tools. Universities, which play an innovative role in education, are using ICT-based approaches to adapt their learning methodology. In this paper, we present a model where students from first-world universities prepare and adapt course contents for use in educational institutions in developing countries. The objectives of this initiative of students' participating in e-learning projects with developing countries are to improve their motivation, develop a set of cross-curricular competencies, and transfer technologies within the scope of university development cooperation.**

Motivation; e-learning; development cooperation; cross-curricular competencies

I. INTRODUCTION

Over the past few years new and increasing concerns have emerged in Europe regarding education-related topics that were not taken into account until now [1]. Higher education, as a source of development, culture and science, is responsible for achieving an additional objective: human development. Educational institutions, and especially universities, are the cradle of the citizens who will determine the direction of progress in our global society in the near future.

Educational priorities have changed, and an academic education —and this applies to any field, including new technologies and technical studies— is no longer considered complete if it does not consider student instruction in topics related to human development and social awareness. An overview of the different problems affecting society means that the involvement of higher education students has to go beyond the scope of projects exclusively related to their field of work.

This change should be made simultaneously by all players in the higher education system. However, it is very common for teaching staff to be reluctant to introduce new methods, partly for obvious reasons, such as the increased workload, and partly due to under-motivation to finally achieve definite educational improvements. On the other hand, students tend to simplify their study methodology to optimize the time they spend on courses. Due to this lack of interest, most participatory methodologies are difficult to implement. This reality is clearly reflected in courses offering the option of assessment either by a final exam or through continuous coursework and group work, where many students opt for the traditional method and reject the educational improvement. Both students and the professors perceive that the workload is heavier, whereas attainment is similar. But, is attainment really the same? Of course, not. So, how can we motivate the two groups? Development cooperation naturally promotes both student motivation and some of the key competencies in higher education. Group work, communication, learning of other languages, awareness through development, and respect for the environment, are but a few of these skills [2]. We propose a methodology using e-learning applied to university development cooperation in Third World educational institutions applying a project-based learning strategy [3], as an effective instrument for motivating professors and students at a First World university, i.e. a highly motivating methodology for students and professors in a developed country. Project-based learning, or rather social project-based learning in this case, should be understood as a model for classroom work and homework that expands student learning with practical and real-world issues. This work with real-world projects is probably the key element of our learning approach that makes it so motivating for professors and students.

Distance education is no longer an experimental method. Educational tradition has, however, stalled the development of this method, which has been regarded as the main source of innovation in education during the past decade. e-Learning is an essential tool for cooperation and can also be used by professors to increase student motivation and training. Western students participating in these projects are involved in the development of society and receive training from the human standpoint. We get an improvement in the quality of available teaching material in developing countries and a wider dissemination of its contents. Additionally, acquired knowledge is consolidated at the same time as it is transferred to third parties. And all this with the added motivation

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provided by the use of their output for both educational and human development.

This proposal has already being successfully tested by the TEDECO (Technology for Development and Cooperation) cooperation group [4] at the Universidad Politécnica de Madrid (UPM) in partnership with the University of Ngozi (UNG) in Burundi. In this context, the cooperation group has exploited its expertise in information and communication technologies to work on a proposal for using ICT tools (adapted e-learning tools) to improve education in developing countries [5].

II. Motivation

Internationalization in higher education, as in scientific research and other educational settings, is bringing together students, professors and researchers from more than one country, some coming from different cultures and social backgrounds [6], at the same university. Partnerships among European member states and their universities or other higher education institutions channelled through the Bologna process is a key component of this process of internationalization [7]. Another priority of higher education focuses on solving problems and responding to the needs and demands of society today, a global society that extends far beyond the European area [8]. Developed countries are now morally indebted to the developing countries; the developing countries' problems should be studied not only by non-governmental organizations but also by research centres and universities from developed countries. All these points are an initial justification for a more global education, aimed at developing not only language skills but also environmental education and intercultural awareness.

Below we justify from different points of view —divided into different sections— the reasons that brought us to develop this proposal linking education and development cooperation to improve the performance in both areas through collaborative work.

A. The European Higher Education Area

Changes in our global society have motivated the promotion of profound changes in education through the European Higher Education Area (EHEA) [9]. Cross-curricular competencies and student motivation have become central issues in the new scenario. The development and assessment of cross-curricular competencies not directly related to core technical knowledge is, however, one of the main problems facing professors during the transition period. A global solution requires adapting educational models and methodologies to achieve these new priorities.

One of the most important cross-curricular competencies is independent work, and Internet is playing a crucial role here. Plenty of free and open source material is available through the web, and students must use this information to complete and adapt their own technical material [10]. When students work on a topic they are only developing the core technical competencies of their specialty. But when students add to their material they are developing some of the cross-curricular competencies that are so difficult to improve through traditional education, such as capacity for analysis and synthesis, ability to work independently, team work, etc. [11].

B. Problems of Universities in Developing Countries

Education is the basis of a country's development process. In developing countries, it is very often impossible to wait until all basic needs have been covered to start up higher education programmes. Also, tackling higher education in a society with serious economic problems and no technical institutions to educate professionals in the area is a massive feat. Cooperation takes care of education. Traditionally, though, it has been more concerned about solving basic necessities than about higher education, which appears to be far removed from the possibilities of some developing countries. However, it is well known that higher education is a key field in the development of these countries, where local professionals will drive future changes. This is the main motivation for university cooperation with developing countries requiring assistance to develop their own adapted curricula and course contents. This is a key activity referred to as university development cooperation (UDC).

The traditional role of Western universities in UDC has often been limited to donations (donors of money, professors, and teaching material among other things). Over the last few years, however, a new concept of UDC has arisen, where universities from developed countries have become active participants working with developing universities. First World universities also gain benefits from this cooperation. This paper aims to conduct a methodological study of these benefits.

C. University Development Cooperation

Over recent years Western universities have become aware of their importance in the evolution of an increasingly global society. In this way, the activity of these universities —mainly (and sometimes exclusively) related to higher education and research— has traditionally focused on the needs of Western societies. However, 20% of the world population is clearly not a representation of global society, and therefore it is quite irresponsible for them to focus on solving the problems of just a small part of the world population and leave the problems of 80% of the population living in developing countries completely unattended.

Development cooperation aims to be the response to new concerns for solutions adapted to developing countries, and it has been included in higher education frameworks. There are codes of conduct signed *en masse* by a considerable number of universities —e.g. major Spanish higher education institutions [12, 13]. Universities are considered active agents of cooperation in the fields of education and research, as they are described in master plans designed by regional [14] and national development cooperation agencies [15].

Closely related to the research and innovation groups working on education currently operating at the UPM, there is a new label to identify groups working on development cooperation at the UPM and other universities. They are called **cooperation groups** and have become important technically highly qualified agents with sound expertise in both higher education and research on development.

D. Relevance of Information and Communication Technologies

Information and communication technologies (ICT) are fundamental in the developed countries where *"Information and communication technologies are transforming the way that individuals, institutions and societies learn, work and live. These technologies offer enormous potential benefits for the conduct of teaching, learning, research…"* [16].

Also ICT are fundamental for developing countries where access to information and communications is the key to development in the 21st century. Fig. 1 illustrates the cross-impact of ICT [17]. ICT is playing an important role in education, especially higher education. E-learning is the most common field relating ICT and education. However, traditional e-learning solutions and contents are designed for education in developed countries. Tools must be redesigned and contents must be adapted for application at developing countries' universities.

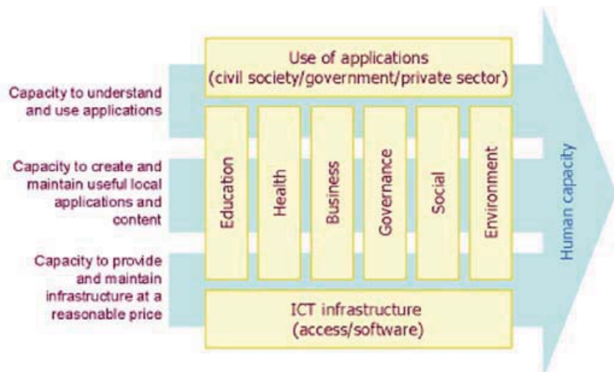

Figure 1. ICT cross-impact [17].

III. E-LEARNING APPLIED TO COOPERATION

Traditionally e-learning in the higher education model, i.e. at university, has been employed to: (1) increase university visibility, (2) extend the educational offer, and (3) as learning "virtualization" [18]. As shown in the last section, however, e-learning is especially interesting within ICT in developing countries, since it can overcome some of the physical and economic obstacles to education. Some of these obstacles that can be overcome by e-learning are the shortage of teachers or the lack of adequate training (especially in technical topics) of the available faculty. Hence technologies that enable distance learning are highly valuable in such environments, and e-learning could be the tool for transferring teaching activities to developing countries.

There are currently several projects using e-learning in developing countries as a support tool for education. Some of these projects are part of a broad educational program, divided into three noteworthy programs:

- The Latin American *Programa de Actualización de Maestros en Educación*[1] (AME) [19], a program specifically focusing on basic education teachers in Latin America using television and distance learning.
- The African Virtual University (AVU) [20].
- The Virtual University of Pakistan (VU), Pakistan's first university based completely on modern information and communication technologies [21].

Although our approach focuses directly on a university in a developing country, these projects are also good candidates for receiving the information that the method proposed here can provide. However, none of these projects has carried out a joint study of benefits for participants at First World universities: motivation, cross-curricular development, etc., encouraging and training students to prepare the necessary topics.

Within the TEDECO cooperation group [4], we published a novel approach (methodology, architecture and implementation) addressing this challenge. This approach included a new term, that is, c&d-learning [5], i.e. learning for cooperation and development. The c&d-learning model is based on the use of the Moodle[2] platform [22], adapted to the needs and infrastructures of developing countries. Not only does the c&d-learning model lead to an adaptation of the educational platform used, but it also proposes the requirements that must be taken into account when preparing the educational content of each course. In this paper we also propose an educational approach focusing on the fact that student participation in a c&d-learning project aims to achieve three objectives: (1) student motivation, (2) cross-curricular development, and (3) technology transfer.

In the remainder of this section we detail our approach. We justify this approach in Section 4, presenting a case study and its results, the experience of c&d-learning developed by UPM students with the UNG. In Section 5, we present the conclusions drawn from the implementation of the proposed method.

A. Scope

There has been much debate and many classifications of what is and what is not e-learning, but this is not the objective of this paper. It is important, though, to clarify some properties and uses of e-learning that must be taken into account when implementing this proposal. For example, depending on the communication and interaction between teacher and students, e-learning can be used as a synchronous or asynchronous (occasionally alternative terms, such as on-line or off-line education, respectively, could be used) teaching aid. Note importantly that e-learning extends the properties of the communication channel between teacher and students, thus providing new educational situations that did not occur in the traditional method. This is the case of an asynchronous communication where a message communicated by the teacher may not be immediately received by students.

In our case, c&d-learning should be classified as an asynchronous- and distance-learning model. First, the model

[1] Primary school teacher refresher course.

[2] Moodle is a course management system (CMS) commonly used in e-learning, also known as a learning management system (LMS) or a virtual learning environment (VLE) [20].

involves distance learning because courses developed as part of this approach are not applied *in situ* since there is a shortage of instructors. Second, the model is asynchronous because cooperation with developing countries does not require a constant or continuous communication. This last characteristic is the main constraint that the c&d-learning must overcome, since it requires the adaptation of course contents and e-learning platforms (designed for First World academic models) [5]. Some causes preventing a continuous communication can be: time difference among countries (which applies, for example, in partnerships between countries from Europe and Latin America, quite a common cooperation partnership), problems with Internet connections, different work schedules, or even cultural differences.

B. Role Description

Before detailing the planning strategy for our approach, this section gives a description of the different roles involved in the proposed methodology. Before we start to describe roles, let us clarify one point: from now on, when we use the term "local" in reference to professors, students or even resources, it should be considered as an indication of locality at the final destination of this educational proposal, i.e. at **universities in developing countries**. On the other hand, if used **without** the term "local", we will be referring to staff, professors, students or resources of **universities in developed countries**.

a) ***Professor*** *(at a First World university)* is responsible for starting this initiative (at a developed country's university), managing its evolution and performing the final evaluation. He or she supervises the process to assure the quality of the result. Furthermore, he or she could also be the beneficiary of the creation of repositories for learning resources [23].

b) ***Students*** *(at a First World university)* are the drive behind this approach, working together with the *Professor* to develop course contents at the same time as they assimilate the key concepts. Although they may not have all the training required to run a course, this approach is applicable thanks to supervision by the *Professor* and the lower academic level at developing countries' universities. In any case, first-year courses that are continued in following years (e.g. Programming I, Programming II) are the best candidates for running this proposal.

c) ***Local Professor*** *(at a Third World university):* Sometimes called *facilitator*[3], he or she is responsible for managing course contents at the target university, i.e. at a local university. He or she may need to perform some or all of the following tasks: present the contents *in situ*, answer questions or extend content, forward queries about user-level technical issues related to the e-learning platform to the *Professor* as necessary.

d) ***Local Students*** *(at a Third World university)* are the students located at the university in a developing country, i.e. the final beneficiaries of this approach.

[3] In the absence of local professors at the local university (i.e. in a developing country), a temporary entity, the facilitator, could possibly assume the role of teacher.

Henceforth the terms professor and student (whether or not they are preceded by the term "local") will be shown in uppercase and italics when referring to a specific role of this proposal, fulfilling the functions described above.

The roles defined above within a full c&d-learning scenario are shown in Fig. 2. All roles are linked by a common e-learning platform. The dotted lines represent all the paths between entities with the potential for content transfer (e.g. content preparation, supervision, evaluation, query resolution, etc.). An asynchronous channel determines communication between *Students* and the *Local Professor* from universities in developed and developing countries, respectively. Although interaction processes are flexible, delegating responsibilities to *Students* regarding course content transfer encourages a valuable communication with the *Local Professor*. In any case, it is essential for the *Professor* and the *Local Professor* to supervise topics, methodologies, assessments and content developed by *Students,* and communication.

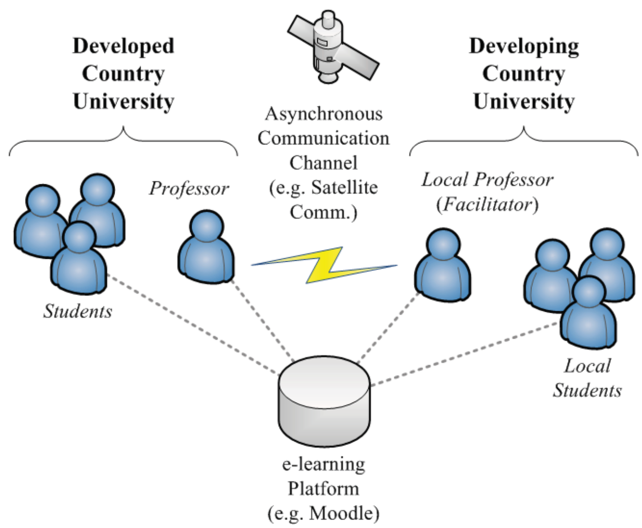

Figure 2. The c&d-learning scenario, including participant roles (*Professor*, *Student*, *Local Professor* or facilitator, and *Local Student*), communication channels and an e-learning platform.

C. Work Planning

The ultimate aim for participants in this initiative is to feed an e-learning platform with adapted course contents. This model delegates course scheduling and execution using the provided material, as well as supervision of course development, to the *Local Professor*. With the proposed delegation of responsibilities, we try to minimize interactions between *Local Students* and the external (non-local) *Professor*. This should bolster the figure of the *Local Professor*. In fact, after a training period teaching one or more courses, the *Local Professor* should be able to reproduce this ability, and dependence on the First World *Professor* should gradually decrease. The proposed educational method can be set up in three phases:

1) Student recruitment: the *Professor* in charge of *Student* recruitment should take into account a number of issues to launch this initiative.

a) Motivation: Development cooperation is a motivation in itself. As shown in the results section, the *Students* involved are volunteers. Since technology transfer is carried out where it is most necessary, development cooperation should be emphasized within the recruitment process.

b) Repetition: One of the main advantages of the proposed method is that the call —message used to engage *Students*— can be repeated periodically during each course. We recommend that the call be repeated and monitored during the development of the proposed approach to encourage student motivation throughout.

Note importantly that *Student* recruitment is a critical element for the success of the proposed approach, but educational methods should not be developed only to deal with the most appealing issues for students. In fact, the *Professor* in charge of these initiatives should use this proposal to complement their course planning to develop further cross-curricular competencies.

2) Initialization and Development: Once a group of *Students* has enrolled in this initiative, the required adaptation of the e-learning concept must be clarified. At First World universities, e-learning may facilitate two well-known models [18]: (1) uploading resources to supplement on-campus education, or (2) tele- or on-line education. Both models have a requirement that is only satisfied in developed countries: student Internet access from home or work. The situation in developing countries is the opposite: students usually only have on-campus access to ICT-based education. Bearing this in mind, content adaptation for *Students* must cover two important issues:

a) Resources self-sufficiency: If possible, the content developed by *Students* should provide methods to cover the complete educational process of each course. Otherwise, further resources must be available for off-line use, i.e. taking into account the limitations of the communication infrastructure in developing countries.

b) Self-assessment: Inclusion of self-assessment mechanisms to help *Local Students* to find out what they have learned.

c) Completeness: Local Students probably will not have access to additional content with which to increase their knowledge and training, and the information necessary to complete or understand an explanation.

Comparing the workload of traditional e-learning professors to the c&d-learning *Professor*, whereas working as an e-learning professor is a full-time engagement, the *Professor* in the proposed approach should transfer almost all responsibilities to *Local Professors*. In fact, their participation focuses mainly on the early phases of generating the course content and the final phases of evaluation. In the meantime, occasional and asynchronous interaction is required to answer advanced questions. This is potentially another argument in favour of motivation, since c&d-learning can be combined with the daily workload of the *Professor* and *Students* involved.

3) Evaluation: Although the main objective of e-learning technologies is to facilitate the move from “blackboard to on-line” education, they can also be used for [18]: (1) self-assessment and organization of the educational methodology, (2) content quality control and analysis, and (3) didactic refresher activities. In developed countries’ universities, student assessment must cover more than just specific knowledge acquired in the respective course. Besides the cross-curricular competencies mentioned in section II [11], the Organization for Economic Cooperation and Development (OECD) suggests three main groups of cross-curricular competencies in higher education [2]. With a project-based learning model [3] as proposed here, the following competencies can be developed and hence evaluated.

a) Use tools interactively (e.g. language, technology). ICT skills are developed through e-learning usage, not only at the user level, but, in this case, at the editor level as well. Regarding languages, when *Students* cooperate with a different country, they must use a foreign language to prepare the course content and communicate with the local university staff.

b) Interact in heterogeneous groups: Compared to First World university environments, personnel working at universities in a developing country are one of the most heterogeneous groups that *Students* are likely to work with in their academic and professional life. Contact with a really different culture is a valuable experience for *Students*, and how they cope with these differences is also an issue to be evaluated.

c) Work independently: In this environment, *Students* become leaders and are responsible for the development of a particular course. Although supervised by a *Professor*, they must make important decisions that may have a significant impact on things such as content extension, assessment implementation or available resources. Key decisions, such as methodological approaches or assessment procedures, are outlined by the supervisor.

Finally, technology transfer can also be evaluated through the final beneficiaries of this initiative, *Local Students* and *Professors*. Traditional mechanisms, such as surveys, academic attainment comparison or course content quality, are suitable methods for such an evaluation and are provided by the actual e-learning platform for use.

IV. CASE STUDY AND RESULTS

In this section we present the case of study and its results. This case of study was carried out as a result of cooperation between Spain’s Universidad Politécnica de Madrid (UPM) and Burundi’s University of Ngozi (UNG). In mid-November 2005, the UPM received a request for cooperation involving teaching staff from UPM teaching computer science courses at the UNG. They replied to the original request by sending two professors from the UPM’s School of Computing. These instructors gave their first classes during the months of April and May 2006. This initial cooperation was followed up by the design of an action plan to promote the self-sufficiency of the UNG based on ICT training and development.

After its initial contact with the UNG, the UPM's university development cooperation group, TEDECO, focused on designing a comprehensive action plan for UNG. It is here where the work of TEDECO really began. This project is divided into three phases, which have been carried out over the past two years. In chronological order, the planned tasks were: (1) the modernization of the computer equipment, (2) the installation of a shared Internet connection, and (3) the adaptation of a platform for planning educational material.

Currently TEDECO is working on the third and final phase described above, where we have started to simultaneously prepare the educational material necessary for the remote provision of courses at the UNG. We have also started to implement the educational methodology proposed here. To do this, we have used the previously developed c&d-learning model and delegated the preparation of the contents of the original materials delivered using e-learning since the 2006/07 academic year.

After the application of the proposed approach, the results can be viewed from two different perspectives. Firstly, we present UPM participation data: number of *Professors*, *Students* and other staff involved in this initiative. Secondly, we also discuss the impact of material provided by *Students* and *Professors* at the local university (UNG). From the analysis of these data we can: (1) evaluate the development of *Students* cross-curricular competencies ―although *Professor* supervision is the main source of evaluation, local course outcomes should be also considered―; and (2) motivation feedback through technology transfer evaluation.

A. Participation

Table I and Fig. 3 summarize the participation data of *Professors*, *Students* and others participants[4] involved in e-learning approaches implemented by the TEDECO cooperation group.

TABLE I. PROFESSORS, STUDENTS AND OTHER STAFF INVOLVED IN THE PROJECT.

Actors	Year			
	2006	*2007*	*2008*	*2009* [a]
Professors	2	4	4	5
Students	2	12	14	17
Others	1	3	0	4
Total	5	19	18	22
Project-based learning [b]	1 (50.0%)	3 (25.0%)	8 (57.1%)	10 (58.8%)

a. On-going year. Data may be incomplete.

b. *Students* involved in project-based learning.

[4] They are mainly former students.

The last row in Table I shows the number and percentage of *Students* over the total number of staff involved in project-based learning (listed in the second row).

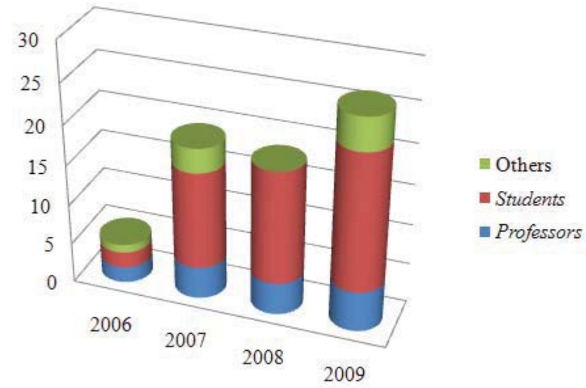

Figure 3. Number of *Professors*, *Students* and other staff involved in e-learning projects within TEDECO since 2006.

As shown in Fig. 3, the final number of participants has increased slowly but fairly constantly since the project kicked off and was consolidated. As the application of the approach has not been extrapolated to other institutions yet, further participation increments are not feasible.

B. Impact at the local university

Table II shows the evolution of the number of *Local Students* of computer science at the UNG. The number of *Local Students* is broken down by course and year. For the first two years, the UNG organized the computer science degree as a three-year course, which was expanded by a further fourth year from 2007 onwards. Row 5 shows the total number of *Local Students*, and rows 6 and 7 list the number of *Local Students* that have graduated in computer science vs. the number of *Local Students* that dropped out of the degree course. The last row in the table shows the evolution of the number of on-line subjects available at UNG [24]: Operating Systems, Programming Methodology, HTML and Web Development, Communications Networks, "*Java et bases de données*" (only French version available), and Linux Network Administration[5].

TABLE II. LOCAL STUDENT EVOLUTION IN COMPUTER SCIENCE AT UNIVERSITY OF NGOZI.

Number of Local Students	Year			
	2005/06	*2006/07*	*2007/08*	*2008/09* [b]
First year	35	55	58	62
Second year	17	19	24	18
Third year	12	14	18	19
Fourth year [a]			40	29

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Number of Local Students	Year			
	2005/06	*2006/07*	*2007/08*	*2008/09* [b]
Total	64	88	140	128
CS Graduates	12	14	40	?
CS Dropouts	11	10	12	?
On-line Subjects		0	3	6

a. For the first two years, 2005/06 and 2006/07, the computer science degree did not include a fourth year.

b. Course units taught during 2008/09 are missing (illustrated by a question mark) because some data are not available or incomplete.

After UPM-UNG cooperation was consolidated, there was a notable increase in the efficiency rate and a drop in the dropout rate. Beyond a positive evaluation of the *Professors* involved in this initiative, these results suggest that the objectives of this approach (cross-curricular competency development, motivation and technology transfer) have been achieved.

V. Conclusions

In this paper we have presented a new method for applying a blended learning model (b-learning) to cooperation and development (c&d-learning). This proposal is based on the experiences of the TEDECO cooperation group at the UPM's School of Computing (Madrid, Spain) in partnership with the UNG School of Computer Science (Ngozi, Burundi). Following a study of e-learning differences applied to a university in a developing country and the implementation of a new methodology, we have conducted an analysis of benefits for participants, *Students*.

In traditional education, students receive the technical material required to acquire some specific competencies from their professors. Generally, students are not involved in the process of preparing, improving or updating course contents. However, we have proven that they are able to deal with such issues after taking the respective course. Independent work, interpersonal skills and teamwork, or foreign language communication are just some examples of the cross-curricular competencies developed by *Students* involved in this initiative. Also, this proposal is also interesting for improving the development of some of the least valued competencies in an engineering or information technologies degree —especially competencies related to ethical or social skills—, such as environmental awareness or ethical commitment to others [25].

In addition, development cooperation has proven to act like a catalyst of motivation, since *Students* got involved in the case study despite limited academic recognition: final-year projects or free choice credits in few cases. If this approach were also incorporated into new academic programmes through cross-curricular competency development, participation would be dramatically improved. However, this is also the main limitation of this approach, the double-edged sword of the participants' status as volunteers. Motivation is enhanced but effectiveness cannot be completely assured in these situations. Results suggest that this problem would be solved if this approach were adopted officially, where *Students,* coordinated by the *Professor* of the respective subject, would work with a *Local Professor* at the target university. They would coordinate and adapt the contents of the subject to the requirements of a developing country. This would increase *Student* motivation in the subject, cross-curricular competency development and, finally, technology transfer from the First World to developing countries.

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Practical Framework of Employability Skills for Engineering Graduate in Malaysia

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***Abstract*— The purpose of this paper is to propose a practical and simple framework of engineering employability skills that will allow the concept to be explained easily and that can be used as a framework for working with engineering graduates to develop their employability before entering workforce. The framework was developed from existing researches on engineering employability skills issues and the requirement of the accreditation of engineering programme. The various skills of employability skills related to engineering included in the framework are discussed and their criteria justified bases on literature review of existing studies. The framework sets out exactly what is meant by engineering employability, in clear and simple terms, and the framework suggests directions for interaction between the various skills. The relationships between the skills within the framework remain theoretical. Further research to test the framework is planned and will be reported in future paper. The framework can be used to explain the concept of employability to those new to the subject, and particularly to engineering students and their future employer. It will be a useful tool for lecturers, careers advisors, trainers, employers and any other practitioners involved in employability skills. It will also be used to develop a model and a measurement tool for engineering employability skills. This paper contributes insights into the linking of graduate attributes, using national accreditation criteria and the framework of engineering employability skills from locally and globally expectation. It will be of value to anybody with an interest in employability issues.**

Keywords- Engineering; framework; employability; graduates; employers

I. INTRODUCTION

Today's engineering professions are continuously experienced major changes in knowledge, equipments, tools, systems and managements. Consequently, engineering firm continuously needs an engineer with a strong theoretical background, and require engineer equipped with employability skills. In order to face new challenges, new opportunities and on-going different circumstances, new engineers have to continually adapt and upgrade necessary skills such as self-learning [13], problem solving [10] and others personal skills [11] that can be applied in different situations. To overcome these phenomena, Higher learning institutions and employers need to have common understanding of which skills should be owned by engineering graduates. Therefore, a number of studies had been conducted to find this set of employability skills, and a few numbers of new frameworks of employability skills have been proposed. However, the aim of this paper is to focus on an acceptable and practical framework of engineering employability for Malaysian engineering graduates that are firmly based on requirement by accrediting bodies and professional bodies and existing research findings in employability skills.

II. OVERSEAS ENGINEERING EMPLOYABILITY SKILLS

The popularity of the employability skills has increased around the world since the 1980s [2]. The concept of employability skills have common purpose which is to recognise an important set of skills that support the effectiveness of practising technical and nontechnical skills in the workplace [2; 5; 6]. DEST 2006 [5] asserts the important of employability skills as a tool to assist learners and candidates for assessment to demonstrate the technical competent and skills to achieve and maintain successful employment outcomes. Employability skills were accepted as being important in a competitive business environment, with greater emphasis now being placed on these skills [6]. The skills are also transferable [14] and applicable from one place to another [2].

The United State of America (USA), United Kingdom (UK), Australia (AUS), Japan and European Union (EU) define the criteria for the framework of engineering employability skills as identified by industry and employers [6]. Following are the criteria of engineering employability skills in these countries that becomes reference to Malaysia. These frameworks on engineering employability skills as shown in Table 1 are used as a guideline for their engineering employers and employee as well as for engineering graduates.

TABLE 1: INTERNATIONAL ENGINEERING SKILLS/ATTRIBUTES REQUIRED FOR ENGINEERING GRADUATES

USA	***UK***	*AUS*	***Japan***	***EU***
ABET ***Engineering Criteria 2000***	***OSC Eng Occupational Standards***	*Engineers Attributes*	***Employable personal qualities***	***Generic Employability Skills***
Ability to apply knowledge of mathematics, science and engineering	Develop engineering products	Ability to communicate effectively, with the engineering team and with the community at large	**Personal skills** 1. Communication skills 2. Personal presentation skills 3. IT and computer skills 4. Problem-solving skills 5. Leadership skills 6. Visioning skills 7. Goal-setting skills 8. Self-assessment skills	**Mastery of one's native language** Including the basics of spelling and sentence structure
Ability to communicate effectively	Develop own engineering competence	Ability to function effectively as an individual and in multidisciplinary and multicultural teams, as a team leader or manager as well as an effective team member	**Attitudes** 1. Responsibility 2. Optimism 3. Curiosity 4. Ambition 5. Desire for challenge 6. Cooperation 7. Vitality	**Critical thinking** Ability to think through a problem or situation, distinguishing between facts and prejudices
Ability to design a system, component, or process to meet desired needs	Improve the quality and safety of engineering products and processes	Ability to manage information and documentation		**Understanding of the basics of maths and science** Particularly to cope with new technology
Ability to design and conduct experiments, as well as to analyse and interpret data	Install engineering products	Capacity for creativity and innovation	**Traits** 1. Initiative 2. Sensitivity 3. Flexibility 4. Individuality 5. Sincerity 6. Creativity 7. A balanced personality 8. An entrepreneurial mind	**Learning techniques** Ability to pick up new skills and adapting to new situations
Ability to function on multidisciplinary teams	Maintain engineering products	Capacity for life-long learning and professional development		**Team spirit** Ability to work in a group
Ability to identify, formulate, and solve engineering problems	Plan and manage engineering projects	Professional attitudes		**Personal discipline** Sense of responsibility
Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	Produce engineering products	Understanding of professional and ethical responsibilities, and commitment to them		**Decision making** Sense of commitment and willingness to take risks;

USA	UK	AUS	Japan	EU
ABET Engineering Criteria 2000	***OSC Eng Occupational Standards***	*Engineers Attributes*	***Employable personal qualities***	***Generic Employability Skills***
Knowledge of contemporary issues				**Initiative** Sense of Curiosity and creativity
Recognition of the need for and an ability to engage in lifelong learning				**Professionalism** Sense of achieving excellence and gaining competitive edge
The broad education necessary to understand the impact of engineering solutions in a global/societal context				**Civic mindedness** Sense of service to the community
Understanding or professional and ethical responsibility				

The Accreditation Board for Engineering and Technology (ABET) of USA required graduates from an accredited programme to have and demonstrate the attributes (educational outcomes) as described in Criterion 3 Basic Level Accreditation Criteria, ABET Engineering Criteria 2000 [4], as listed in first column, Table 1. Meanwhile, UK's engineering graduates are required by engineering industry to accomplish the competencies in OSC Eng Occupational Standards as reported by Dodrige [2]. Second column, Table 1 lists the competencies in OSC Eng Occupational Standards. As an Australian professional body and an accrediting body, the Engineers Australia (EA) developed a suite of professional attributes in engineering competencies based on the findings of the review in the development of engineering employability skills for undergraduate students. The professional attributes included in the Engineers Australia competency standards are listed in third column, Table 1. In Japan, a practical industrialized curriculum in engineering had engaged to the Japan Accreditation Board for Engineering Education (JABEE) guideline to integrate employable personal qualities into the academic curriculum in order to generate skilled engineers [11]. Column 4, Table 1, presents the Employable personal qualities practiced in Japan. Lastly, in Column 5, Table 1, lists the generic employability skills proposed by The European Round Table of Industrialists (ERT) in European Union (EU).

Malaysian engineering education mainly guided by accrediting body, Engineering Accreditation Councils (EAC) of Malaysia and the Malaysian Quality Assurance (MQA) Department of the Ministry of Higher Education Malaysia. EAC is the body appointed by Board of Engineers Malaysia (BEM) for accreditation of engineering programme in Malaysia. Accreditation policy required engineering graduates to have the necessary attributes, skills and competencies reflected in the graduate outcomes specified in EAC Manual. According to study done by Basri [4] and Abdullah [1], Malaysian employers agreed that more than 70% of the attributes for engineers in EAC manual are important. Table 2 shows the attributes required by EAC.

TABLE 2: ENGINEERING ATTRIBUTES REQUIRED BY EAC (MALAYSIA)

Attributes
a) ability to acquire and apply knowledge of science and engineering fundamentals;
b) ability to communicate effectively, not only with engineers but also with the community at large;
c) in-depth technical competence in a specific engineering discipline;
d) ability to undertake problem identification, formulation and solution;
e) ability to utilise a systems approach to design and evaluate operational performance;
f) understanding of the principles of sustainable design and development;
g) understanding of professional and ethical responsibilities and commitment to them;
h) ability to function effectively as an individual and in a group with the capacity to be a leader or manager as well as an effective team member;
i) understanding of the social, cultural, global and environmental responsibilities of a professional engineer, and the need for sustainable development;
j) expectation of the need to undertake lifelong learning, and possessing/acquiring the capacity to do so.

Source: EAC Manual

Based on the EAC requirement and the employability frameworks discussed above, this paper try to propose the practical framework of employability skills for engineering graduate in Malaysia for this near future. However, innovations, developments and technologies keep on changing in the world which requires the frameworks to be revised and to be updated as needed by industries.

III. DEFINITION OF ENGINEERING EMPLOYABILITY SKILLS

Skill is an ability to perform a specific task [5] and employability is about having the capability to gain initial employment, maintain employment and obtain new employment if required [8]. Employability skills was defined as 'those basic skills necessary for getting, keeping, and doing well on a job' by Robinson [12] and as 'skills required not only to gain employment, but also to progress within an enterprise so as to achieve one's potential and contribute successfully to enterprise strategic directions' by DEST 2002 [5]. Based on above definitions and other researches result [1; 2; 4; 5; 6; 7], hence, *engineering employability skills* can be defined as:

> *'Ability to perform engineering related skills, knowledge and personal attributes to gain employment, maintain employment and succeed in the engineering field.'*

Engineering employability skills are highly related to technical and non-technical skills or abilities. This definition and the overseas frameworks have been used as a starting point to develop a new theoretical framework for Malaysian engineering employability skills. This proposed Malaysian Engineering Employability Skills Framework (MEES) can be used as a guideline in training package and qualification in Malaysia. Every qualification is suggested to have an Employability Skills Report to describe how each of the employability skills is addressed in that qualification and embedded in the outcomes of the individual units of competence.

IV. PROPOSED ENGINEERING EMPLOYABILITY SKILLS FRAMEWORK FOR MALAYSIA

Employers and leading engineers in Malaysia agreed that engineering graduates are lacking of oral and written communication skills [3], generic skills and nontechnical skills [9; 10; 3; 2]. They required new engineers to perform engineering related skills and knowledge effectively. The fact that an engineering labour market becoming more knowledge-based and global, the importance of developing recognised employability skills globally become more critical [6; 9; 3; 2]. Therefore, this study proposes a **Malaysian Engineering Employability Skills** (**MEES**), a framework of engineering employability skills that intended to provide a framework for engineering related programmes. It can be used as a guide to generate skilled engineers that ready for industry practice locally and internationally, and as a benchmark for engineering graduates to be skilled and competent engineer. This framework was derived from existing researches on engineering employability skills issues, developments in other national frameworks [2; 6], literature on the views of Malaysian employers [1; 2; 4; 5] and the requirement from accrediting bodies of engineering programme. MEES satisfies the criteria and inline with the requirements of the Accreditation Board for Engineering and Technology (ABET), the Engineering Accreditation Councils of Malaysia, the Board of Engineers Malaysia and the Malaysian Quality Assurance Department of the Ministry of Higher Education Malaysia, Washington Accord and also satisfies qualification criteria of other professional bodies. Yet, the proposed framework of MEES is still open for consultation, discussion and debate in Malaysia. Following (Figure 1) is the Framework of MEES and the components made up for the framework.

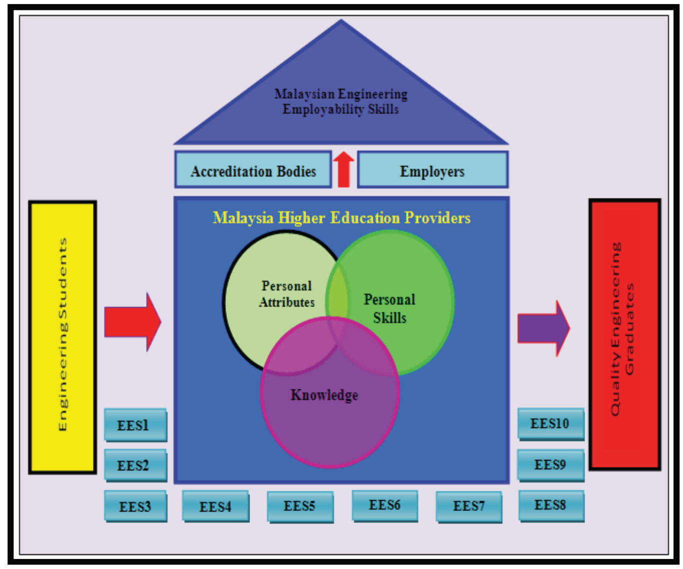

Figure 1: Framework of MEES

MEES comprises three main components: personal attributes, personal skills and knowledge. These three main components are integrated of communication skills (EES1), teamwork (EES2), lifelong learning (EES3), professionalism (EES4), problem solving and decision making skills (EES5), competent in application and practice (EES6), knowledge of science and engineering principles (EES7), knowledge of contemporary issues (EES8), engineering system approach (EES9) and competent in specific engineering discipline (EES10). Key components of the MEES framework is comprised of:

I. **Personal attributes: -** These attributes have been identified [2 − 11] as an ability needed to enable the engineer work well and effectively with others on a job and society.

EES1- Communication skills
EES2- Teamwork
EES3- Lifelong learning
EES4- Professionalism
EES5- Problem solving and decision making skills

II. **Personal Skills: -** These skills considered in an applied context which provide the foundations to gain employment maintain employment and succeed in the engineering field.

EES1- Communication skills
EES2- Teamwork
EES5- Problem solving and decision making skills
EES6- Competent in application and practice
EES10- Competent in specific engineering discipline

III. **Knowledge: -** knowledge which provides the necessary understanding of scientific and technologies principles to gain employment maintain employment and succeed in the engineering field.

EES3- Lifelong learning
EES5- Problem solving and decision making skills
ESS7- Knowledge of science and engineering principles
EES8- Knowledge of contemporary issues
EES9- Engineering system approach

The specific skills of MEES related to engineering included in the framework are justified based on literature review of existing studies, attributes required by accrediting bodies and graduate profile of professional bodies. The framework sets out exactly what is meant by engineering employability skills, in clear and simple terms as presented in Table 2, and the framework suggests directions for interaction between the various skills that being identified. It is obvious that in engineering students are recommended to develop their employability skills in conjunction with their subject knowledge while they are still in undergraduate studies. The higher education providers shall furnish their graduates with attributes that satisfy local requirement and global criteria. These skills are very important for new engineers as well as for engineers to succeed in their profession and being promoted [5; 6].

TABLE 2: MALAYSIAN ENGINEERING EMPLOYABILITY SKILLS (MEES) FRAMEWORK

Code	Skills
EES1	**Communication skills** Ability to present ideas with confident and effective through aural, oral and written modes, not only with engineers but also with the community at large. Engineering graduates should have the skills sufficient to: 1. *Speak in clear sentences,* 2. *Give clear direction ,* 3. *Listen and ask question,* 4. *Ideas presented with confident and effective,* 5. *Speak and understand more than one language.*
EES2	**Teamwork** Ability to function effectively as an individual and in a group with the capacity to be a leader or manager as well as an effective team member. Engineering graduates should have the skills sufficient to:
Code	Skills
	1. *The ability to function effectively as an individual,* 2. *Understand the role in a group,* 3. *Work in a group as an effective team member,* 4. *Accept and provide feedback in constructive and considerate manner,* 5. *Work in a group with the capacity to be a leader*
EES3	**Lifelong Learning** Ability to recognize the need to undertake lifelong learning, and possessing / acquiring the capacity to do so. Engineering graduates should have the skills sufficient to: 1. *Recognize the need to undertake lifelong learning,* 2. *Possessing and acquiring the capacity to undertake lifelong learning,* 3. *Able to engage in lifelong learning,* 4. *Set their personal learning targets,* 5. *Plan to achieve their learning goal(s)*
EES4	**Professionalism** Ability to understand the social, cultural, global and environmental responsibilities of a professional engineer, and commitment to professional and ethical responsibilities. Engineering graduates should have the skills sufficient to: 1. *Understand the social responsibilities,* 2. *Understand the cultural and global responsibilities,* 3. *Understand the environmental responsibilities,* 4. *Commitment to professional responsibilities,* 5. *Commitment to ethical responsibilities.*
EES5	**Problem solving and decision making skills** Ability to undertake problem identification, apply problem solving, formulation and solutions. Engineering graduates should have the skills sufficient to: 1. *Undertake problem identification,* 2. *Implement problem solving,* 3. *Apply formulation and solution ,* 4. *Be creative, innovative and see different points of view in solving problems,* 5. *Analyse and identify the root cause of the problems.*
EES6	**Competent in application and practice** Ability to use the techniques, skills, and modern engineering tools. Engineering graduates should have the skills sufficient to: 1. *Use the necessary techniques for engineering practice.* 2. *Use the necessary skills for engineering practice.* 3. *Use the modern engineering tools and software.* 4. *Work toward quality standards and specifications.* 5. *Assemble equipment following written directions.*
EES7	**Knowledge of science and engineering principles** Ability to acquire and apply knowledge of engineering fundamentals. Engineering graduates should have the skills sufficient to: 1. *Acquire knowledge of engineering fundamentals such as Mathematics and Science.* 2. *Apply the knowledge of engineering fundamentals,* 3. *Select and use proper tools and equipments for specific job / task,* 4. *Access, analyse and apply skills and knowledge of sciences and engineering,* 5. *Understand of principles of sustainable design and*

Code	Skills
	development.
EES8	**Knowledge of contemporary issues** Ability to continue learning independently in the acquisition of new knowledge, skills and technologies. Nowadays, the use of information, communication and computing technologies are very essential in the knowledge-based era. Engineering graduates should have the skills sufficient to: *1. Continue learning independently in the acquisition of new knowledge, skills and technologies.* *2. Use of information technologies,* *3. Use of communication technologies in the knowledge-based era,* *4. Use of computing technologies,* *5. Read news paper.*
EES9	**Engineering system approach** Ability to utilize a systems approach to design and evaluate operational performance. Engineering graduates should have the skills sufficient to: *1. Utilize a systems approach to design,* *2. Evaluate operational performance,* *3. Design systematically* 4. *Analyse engineering design* 5. *Demonstrate a knowledge and understanding of engineering system for management and business practices.*
EES10	**Competent in specific engineering discipline** Ability to acquire in-depth technical competence in a specific engineering discipline, competent in theoretical and research engineering and perform basic entrepreneurial skills. Engineering graduates should have the skills sufficient to: *1. Acquire in-depth technical competence in a specific engineering discipline.,* *2. Apply technical skills in a specific engineering discipline effectively,* *3. Design and conduct experiments,* *4. Analyse and interpret data,* *5. Knowledge in multidisciplinary engineering.*

Sources: ABET, EAC Manual, MQA, DEST 2006, Engineers Australia competency standards, OSC Eng Occupational Standards, JABEE, Washington Accord 1989 and The Future of Engineering Education in Malaysia, 2007.

National and international engineering accreditation criteria have a set of graduates' attributes that require the engineering graduates to be able to demonstrate these attributes after completing the study. The development of attributes and skills for engineering graduates will definitely link to the national and international engineering accreditation requirements. The local and global framework of engineering employability skills have to be parallel to local accreditation criteria. The local accreditation criteria satisfy the international accreditation criteria. Table 3 shows how the accreditation criteria and the framework of engineering employability skills from local and international can link graduates to a employable and marketable graduates, locally and globally.

TABLE 3: INTERNATIONAL, NATIONAL AND FRAMEWORK

International Accreditation Criteria	National Accreditation Requirement	Framework	Result
ABET Engineering Criteria 2000 (USA) ***OSC Eng Occupational Standards (UK)*** ***Engineers Attributes (AUS)*** ***Employable personal qualities (Japan)*** ***Generic Employability Skills (UE)***	MQA EAC	MEES	Employable And Marketable Engineering Graduates

V. CONCLUSION

The overview of overseas literature on framework for engineering related skills in this study has identified a renewed interest in engineering-related employability skills. In the study, this framework has been referred to as *Malaysian engineering employability skills* (MEES). The proposed framework inline with the work that has been undertaken overseas, particularly in Australia, the United Kingdom, the United States of America, Japan and European United. MEES comprises the personal attributes, personal skills, and knowledge that are required by stakeholders/employers [1; 2; 7] to enable engineering graduates to enter workforce, and progress in career path. The term e*mployability "*signals a connection to the world of work that is dynamic and long-term in nature" [6]. The identified technical and nontechnical skills included in the framework are accepted as commonly applicable in the all area of engineering. Adoption of this framework can create future opportunities for new engineer to become professional engineer. This framework can be a guideline to new engineers and "come-back" engineers to become employable and allowing them to remain as a valuable employee all time. The framework can also help engineers to develop their career and move up within the organisation.

The framework can be used to explain the concept of employability to those new to the subject, and particularly to engineering students and their future employer. It will be a useful tool for lecturers, careers advisors, trainers, employers and any other practitioners involved in employability skills. It would be useful for further research in developing a model and a measurement tool for engineering employability skills. This paper contributes insights into the linking of graduate attributes, using national accreditation criteria and the framework of engineering employability skills from local and international expectation.

Data collection and data analysis is still ongoing but it is expected that in-depth analyses of the framework will yield more insight to the implications of these findings for practice and policy making. Of interest would be comparisons of employer expectation ratings on the important of employability skills attributes should be own by graduates with employer perception ratings on the satisfactory of employability skills attributes own by graduates they hired. Some of these implications include a better understanding of how employers' expectations compare with that of employers' perceptions, and the implications such understanding might have on education and training.

However, as knowledge, technologies and workplace processes keep on changed and improved, there will be a need for ongoing skills development in employees for emerging new occupations and changing skills requirements [4; 6; 7; 13]. Continuously studies and researches need to be done to suit in the changes locally and globally.

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A Proposal for the Evaluation of Final Year Projects in a Competence-based Learning Framework

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Abstract— **The authors propose a system for the assessment of Final Year Projects (FYPs) whose educational outputs have been defined previously in terms of competences. For building the proposal, eleven pre-defined competences were ranked and a different weight was assigned to each one. The ranking was made individually by all the authors following a blind two-step process. The first step consisted in ordering the competences by relevance and the second step in grading that relevance for each pair of competences having consecutive positions in the list. As a result, an overall weight was computed for each competence and the final proposal was produced by averaging the individual proposals. In addition, three moments are defined for the assessment of FYPs: the FYP process itself, the written report and the oral presentation. Bearing in mind this, the competences that can be evaluated in each moment are identified and a specific assessment form for each moment is also proposed.**

Keywords-component; engineering education, student assessment, competence-based learning, final year projects

I. Introduction

Project-based learning (PBL) has been recognized for long as a very valuable tool for engineering courses, since it helps students in developing skills that are closely linked to the execution of professional engineering tasks [1]. The recognition of this value of PBL has lead to the inclusion of project development activities in engineering courses [2], being the "Final Year Project" (FYP) the most remarkable of these.

In the currently ongoing process of creating the European Higher Education Area [3], the educational outcomes of university courses are being defined in terms of competences that are to be acquired by the students in order to get their degrees. Significantly, competences related to project management and development seem to be becoming relevant even for non-engineering courses [4]. In this context, both a definition of the pedagogical content of FYPs in terms of competences and a systematic assessment system linked to those competences are needed.

The issue of defining the educational outcomes of FYPs was approached by the authors in a previous work [5]. Within that work a set of eleven competences relevant for FYPs were identified, using the basis provided by [4] and [6]. Also in [5], competences were broken down into specific learning objectives and student tasks to be realized during the FYP were pointed out.

However, in authors' view, the question of defining a systematic approach to the evaluation of FYPs has not been satisfactorily solved so far. While it is true that the problem of assessing student projects is not new and that rubrics are becoming a standard for such assessment [7], the definition of rubrics for all the assessable aspects of FYPs is cumbersome. Moreover, filling such rubrics could be too time-consuming for the juries of the projects and an excessive level of detail could also mislead the attention of the juries towards too specific aspects of the work, thus making them lose the global view [8].

Another aspect of the evaluation of FYPs that is not defined yet, to authors' knowledge, is the ranking of competences, that is, the specification of which aspects should contribute the most to the final marks assigned to the students. Although a weighted average of different aspects was proposed in [9], such proposal did not consider competence-based learning; therefore it is not coherent with the current trends in the design of university courses in Europe.

Within this paper, the authors propose a system for the assessment of FYPs whose educational outputs have been defined accordingly to [5]. For making the proposal, the eleven selected competences were ranked and a different weight was assigned to each one. Also starting from the work in [5], but simplifying the therein described proposal, three moments are defined for the assessment of FYPs: the FYP development process itself (evaluated by the supervisor), the written report and the oral presentation (both evaluated by a jury). Bearing in mind this, the competences that can be evaluated in each moment have been identified and a specific assessment form for each moment is also proposed within the paper. In the design of the forms, both the simplicity and the prevalence of global aspects have been pursued.

II. Educational Outcomes

The definition of the educational objectives of FYPs in [5] was done by relating the experience of the authors in FYP supervision to a selected set of competences drawn from [4] and [6]. Within that approach, learning outcomes were

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structured in four levels of abstraction: classes of competences, competences, learning objectives and project achievements. While this structure provided a comprehensive means to relate project activities to learning outcomes expressed in terms of competences, it was too detailed to be manageable both by students and lecturers as a guidance for the learning process associated to FYPs. Consequently, herein only the two levels with the highest degree of abstraction have been considered for the formal definition of learning outcomes: classes of competences and competences, as specified next.

A. *Classes of competences*

The educational purposes of the FYP can be classified, at the most general level, in four types or classes of competences:

1) **Intellectual competences**: related to the way reality is analyzed, reasoning on it is produced and proposals to change it are generated.

2) **Instrumental competences**: related to knowledge, techniques and working procedures that must have been acquired prior to the beginning of the FYP.

3) **Managerial competences**: related to the planning and implementation of activities, be them either individual or in group.

4) **Social contextualization competences**: related to analyzing and previewing the interaction between technology and the social context in which it takes place.

B. *Competences*

Individual competences that must be improved during the development of the FYP have been identified within each group.

1) Intellectual competences

C-I. **Competence for analyzing and synthesizing**: capacity for compiling, comprehending, interpreting and evaluating information and data relative to a technological problem in such a way that its main aspects can be easily identified.

C-II. **Competence for applying knowledge to practice**: capacity for solving specific problems making use of the specialized knowledge of the correspondent technology and for conceiving, if needed, new systems or devices that help in achieving the objectives and requirements of the undertaken problem.

C-III. **Competence for making research**: capacity for generating new knowledge from hypothesis and data, making use of the scientific method.

C-IV. **Competence for scientific and rational analysis**: attitude for systematically analyzing reality from a rational-scientific point of view, which is characterized by the appropriate use of theories and models, the production of coherent interpretations of facts, the critical analysis and the forming of personal opinions and judgments.

2) Instrumental competences

C-V. **Competence for dealing with the basic knowledge of the technological area**: familiarity with the basic concepts of the correspondent knowledge and technological area and capacity to increase the personal knowledge through autonomous study.

C-VI. **Competence for managing information**: capacity for finding information in bibliographies, distinguishing between primary and secondary bibliographic sources, making good use of libraries and locating information on the World Wide Web while assessing its reliability.

C-VII. **Competence for performing basic tasks with computers**: capacity for creating and storing information in several formats, for complying with norms relative to those formats, for communicating making use of computer networking, for using on-line resources, for registering experimental data in electronic format and for using software specific to the correspondent knowledge area.

C-VIII. **Competence for language communication**: capacity for elaborating written texts and oral dissertations following orthographic and grammatical rules, with a coherent ordering of ideas and arguments and with different levels of detail; having good fluency in a second language, at least in reading comprehension.

3) Managerial competences

C-IX. **Competence for inter-personal relations**: capacity for listening others' opinions and views, for using verbal and non-verbal codes, for working in a team and, if necessary, leading it, for presenting proposals and projects, for debating, for conducting interviews, for generating interactive environments, for interacting with people coming from diverse social and cultural contexts.

C-X. **Competence for task managing**: capacity for organizing time, for setting priorities, for working under pressure, for complying with compromises in results and time.

4) Social contextualization competence

C-XI. **Competence for analyzing the social context**: consciousness of the existence and the origin of social conditions, restrictions, beliefs and usages and capacity for assessing the social and ethical impact of technological projects.

As stated before, the educational purposes of the FYP could be further concretized. However, in the authors' view, this level is enough both to inform students on what they are expected to do and to design a competence-based FYP assessment system, as proposed in next section.

III. EVALUATION

A. *Assessment procedure*

As stated in section I, the student evaluation in a competence-based learning paradigm should be competence-based too [8]. Therefore, the herein proposed procedure for FYP assessment consists in directly evaluating up to which level the student has acquired each of the 11 competences involved in FYPs. In this way, the students' attention is not deviated towards specific aspects whose artificially increased relevance could bias the overall educational aim and, at the same time, the coherence between FYP educational objectives and assessment process is kept.

However, the diversity of competences to be evaluated results in a corresponding diversity of evaluation times and people involved. Considering both common practice and the FYP achievements listed in [5], at least three evaluation moments and agents can be identified:

- **Implementation process**: the work of each student can be assessed continuously by the FYP supervisor during group and individual meetings and also considering the project plan and the cooperation with other students.
- **Final report**: evaluated by a board formed by lecturers.
- **Oral presentation**: also evaluated by a board of lecturers with possible inclusion of colleague students.

Table I summarizes the authors' view on which competences can be evaluated in each of the three abovementioned moments. A detailed justification for this relation between competences and moments can be found in [5]. From this table, it becomes clear that the three evaluation moments are complementary in the sense that none of them can account for all the competences. Moreover, according to the same table, the evaluation board needs at least two of these views of the project to have a complete overview of it. Tables II, III and IV contain the questionnaires proposed for the evaluation at each of the three moments.

Regarding the issue of how to combine the marks given in all moments to produce a final mark for each competence, a variety of possible procedures exists, but the authors propose a consensus among the evaluators built in a private meeting after the oral presentation.

TABLE I. COMPETENCES AND EVALUATION MOMENTS

Competence	Impl.	Rep.	Pres.
C-I Analyzing and synthesizing	X	X	
C-II Applying knowledge to practice	X	X	
C-III Making research	X	X	
C-IV Scientific and rational analysis	X	X	X
C-V ... knowledge of the technological area	X	X	X
C-VI Managing information	X	X	
C-VII Performing basic tasks with computers	X	X	X
C-VIII Language Communications		X	X
C-IX Inter-personal relations	X		X
C-X Task managing	X		
C-XI Analyzing the social context	X	X	X

B. *Competence ranking and weighting*

A second question that arises in the design of the evaluation process when a final numeric mark has to be assigned to the FYP of a student is how to rank the competences and how to weight the marks given to each one in order to obtain a global mark. For solving this question, the authors have followed a two-stage procedure inspired by [10]:

- As a first step, each author has ordered the 11 competences by their relevance for FYPs.
- Secondly, a weight has been assigned to each competence relative to the following one in the ordered list. After that, a simple set of linear equations has allowed to convert these weights to a set summing 100%.

TABLE II. QUESTIONNAIRE FOR THE EVALUATION OF THE ORAL PRESENTATION

Competence	Mark
C-IV Scientific and rational analysis: The student has presented his or her work in a well structured way. He or she has adequately justified his or her decisions, proposals and answers.	
C-V ... knowledge of the technological area: The student has shown good knowledge of the subject in which the project is framed. He or she has used specific vocabulary properly and avoided superficial analyses.	
C-VII Performing basic tasks with computers: The student has adequately used supporting software for the presentation, shown well elaborated graphs and, if needed, performed software demonstrations.	
C-VIII Language communication: The structure of the presentation has been appropriate. Repetitions and ambiguities have been avoided. The language has been clear and concise and using appropriate vocabulary and register. The presentation length has been adapted to its contents.	
C-IX Inter-personal relations: The student has succeeded in maintaining the attention of the audience. He or she has answered all questions without avoiding any and recognized own mistakes. His or her position in the room and speech loudness and speed have also been appropriate. Reading has been avoided.	
C-XI Analyzing the social context: The student has spoken about the social context and relevance of the work. Topics and superficial approaches in analyzing ethical issues have been avoided. He or she has shown sensitivity towards the social impact of the project.	

TABLE III. QUESTIONNAIRE FOR THE EVALUATION OF THE IMPLEMENTATION PROCESS

Competence	Mark
C-I Analyzing and synthesizing: The student has understood the proposed problem and all its conditions and circumstances. He or she has been autonomous in critically searching, gathering and processing information. He or she has succeeded in relating the problem to others previously approached.	
C-II Applying knowledge to practice: The student has been autonomous in applying scientific knowledge and he or she has proposed well founded hypothesis and methods. Changes in methods and objectives have been well reasoned. Required time and equipment resources have been defined beforehand.	
C-III Making research: The student has shown ability to approach problems at different levels of abstraction, to design experiments, to process data using appropriate statistical and mathematical tools, to handle specific instrumentation and to interpret results.	
C-IV Scientific and rational analysis: The student has identified all the different parts of the problem. He or she has presented and defended arguments in discussions with the supervisor and with other students. He or she has decided based on objective criteria and has used multidisciplinary knowledge when needed.	
C-V ... knowledge of the technological area: The student has shown to be competent in dealing with procedures and concepts of his or her knowledge area and also in handling specific instrumentation. He or she has been autonomous in looking for information that helped in solving his or her doubts.	
C-VI Managing information: The student has been autonomous in gathering and selecting information. He or she has resorted to several sources of information and has been able to assess the reliability of each one. He or she has made use of on-line resources provided by the university.	
C-VII Performing basic tasks with computers: The student is skilled in managing diverse data and document formats, he or she has usually accessed to network resources and services and has appropriately used data processing software and also software specific to his or her knowledge area.	
C-IX Inter-personal relations: The student has regularly attended to meetings with the supervisor and has been able both to discuss and defend his or her approaches and to rectify them when needed. He or she has shared ideas with colleagues and, if required, he or she has participated in joint projects and coordinated part of the work.	
C-X Task managing: The student has written a project plan, kept a log book of the project activities, respected foreseen deadlines and activities and adjusted the plan when needed.	
C-XI Analyzing the social context: The student has evaluated results bearing in mind their applicability. He or she has included ethical and social issues in the context analysis.	

These two steps have been taken independently by each author, without knowing the proposals of the rest. Averaging the resulting weights results in the list of relative relevancies of competences included in table V.

Beyond the specific results shown in this list, which obviously are prone to variations depending on the specific group of people involved in its elaboration, the following aspects can be highlighted:

- All authors except for one agree that competences C-II and C-V are among the four most relevant.
- All authors except for one agree that competence C-VIII has a medium relevance.
- All authors except for one agree that competence C-III is among the four least relevant.
- • All authors agree that competence C-XI is among the three least relevant.

Regarding all this analysis, it should be recalled that the issue being studied here is the relevance of each competence in the educational contents and assessment process of FYPs in an engineering course, not the importance of each competence either in professional life or in other contexts. For instance, being competent in performing tasks with computers is undoubtedly very relevant for engineers, but such competence should be developed mainly before reaching the FYP. Therefore, C-VII plays a minor role in the marking of the FYP. Conversely, while certain research tasks can be developed during the FYP, the competence for making research is more closely related to higher educational levels (eg. doctorate). Again, this is the reason why C-III appears among the least relevant competences.

TABLE IV. QUESTIONNAIRE FOR THE EVALUATION OF THE FINAL REPORT

Competence	Mark
C-I Analyzing and synthesizing: Problem description and analysis are based on a sufficiently wide up-to-date specialized bibliography. The literature review has clearly synthesized contents, it is well structured and it includes a judicious analysis of the bibliography while avoiding plagiarism. The hypothesis and/or design criteria are clearly linked to the review of the state of the art. Data collected during the project have been adequately organized and analyzed and they provide a clear foundation for the conclusions.	
C-II Applying knowledge to practice: Project hypothesis and objectives are clearly stated, well founded on theoretical knowledge and realistic. Project objectives are original and result from a personal contribution of the student. The proposed methodology is coherent with the objectives, it is clearly explained and justified and it leads to the reported results.	
C-III Making research: Unsolved issues have been identified and corresponding hypothesis have been stated. Experiments and results have been adequately carried out and collected in order to confirm or reject such hypothesis. Data analysis has been unbiased and it clearly supports the conclusions. Findings and conclusions have been discussed and contrasted to previous results present in literature.	
C-IV Scientific and rational analysis: The contents of the final a report are well organized. The approach to the project is systematic. Statements and interpretations are correctly reasoned or founded in adequate bibliography.	
C-V ... knowledge of the technological area: Project implementation has involved knowledge related to the university course, and part of it has required autonomous study by the student. Conceptual errors have been avoided and, if needed, specific instrumentation has been correctly used and its specifications and using requirements have been reported.	
C-VI Managing information: The final report includes a list of references. All references have been cited in the text. Reference format is as specified. Sources of all copied material have been cited.	
C-VII Performing basic tasks with computers: The format specifications of the document have been respected. Usage of styles and formats is coherent throughout the whole document. Appropriate software has been used for generation of graphics and data processing.	
C-VIII Language communication: The structure of the report is correct. Headings and content are coherent. Both repetitions and ambiguities are avoided. The text is clear and concise. The length of the final report is adequate for its contents and it does not contain either syntactic, orthographic or semantic errors. The bibliography is multilingual.	
C-XI Analyzing the social context: The project context is mentioned and described. Both practical and ethical consequences of the project have been considered.	

TABLE V. RELATIVE RELEVANCE OF COMPETENCES

Rank	Competence	Weight
1st	C-V Dealing with the basic knowledge of the technological area	15%
2nd	C-II Applying knowledge to practice	14%
3rd	C-I Analyzing and synthesizing	13%
4th	C-VI Managing information	11%
5th	C-X Task managing	9%
6th	C-IV Scientific and rational analysis	9%
7th	C-VIII Language communication	8%
8th	C-IX Inter-personal relations	7%
9th	C-VII Performing basic tasks with computers	6%
10th	C-III Making research	4%
11th	C-XI Analyzing the social context	4%

IV. DISCUSSION

Within this paper, the authors have presented an overview of an evaluation proposal for FYPs in engineering university studies. While the details of the proposal may be somewhat biased by the professional background of the authors (6 engineers, 1 physicist and 1 linguist, all giving lectures in a telecommunications engineering faculty) and the specifics of their institution, the approach can be easily transferred to other contexts, as reasoned in the next paragraphs.

The assessment procedure is closely related to the educational objectives of the FYP by means of the so called project achievements enumerated in [5]. The proposed procedure follows the rule of directly assessing the relevant educational outcomes, namely the competences, as suggested in [8]. These two criteria, together with the search for simple questionnaires that can be contained within a single sheet of paper, have served as a basis for the proposal. As for the assignment of marks to each competence, although the proposal allows certain degree of subjectivity, it could be complemented with a rubric-type guide for evaluation. It should also be noted that, intentionally, no pre-defined scale for the marks has been given. In the authors' view, this is not a critical aspect of the proposal and it can be adapted to specific circumstances. Still, if an objective orientation were to be given, a scale consisting of four to five levels seems to be appropriate, according to [7] and [11].

Regarding the ranking and weighting of competences, the ordered list presented in section III-B is undoubtedly a result of the personal views of the authors. Yet, some aspects of the proposal can be generalized. In the first place, the two-stage approach (ranking in the first place, weighting in the second place) derived as a simplification of the proposal in [10] can be adopted within any group to identify the most and least relevant competences. In the second place, it is also significant that, after an independent ranking-and-weighting process, there was a remarkable degree of agreement in that:

- the knowledge of the technological area and the capacity of applying theory to practice are the most relevant competences to be developed and assessed during the FYP,
- making research and analyzing the social context are among the least relevant and
- the relevance of language communication should not be diminished.

Last, the whole approach could easily be extended to the final works in higher educational levels (e.g. MSc or PhD). As considered in [6], the set of competences to be developed at graduate and postgraduate levels is mainly the same, though the particularization of those competences for each educational level should result in different educational objectives. Thus, the evaluation process could remain basically unchanged but with different weights assigned to each competence, since the purpose of postgraduate studies is not the same as that of undergraduate courses.

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Session 05C Area 2: Innovative Engineering Courses and Labs - Courses

Learning network protocols through WSN based games

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An Interdisciplinary Practical Course on the Application of Grid Computing

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Introducing Scenario Based Learning: Experiences from an undergraduate electronic and electrical engineering course.

Day, Sally; Kenyon, Tony; Mitchell, John; Mitrofanov, Oleg; Renaud, Cyril; Rio, Miguel; Romans, Ed; Savory, Seb; Thomsen, Benn

UCL (United Kingdom)

Mechatronics E-course for regular students and adults: realization and comparison of efficiency

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Distance Practices in Subjects of Automatic Control

Aracil, Rafael; Ferre, Manuel; García, Ángel; Hernández, Luis; Pinto, Enrique; Santana, Iván

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A web-based e-learning tool for UML class diagrams

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Learning network protocols through WSN based games

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Abstract—**Learning network protocols is not an easy task. We use them every day, but they have become transparent, as they are integrated in the Operating System. Its use also implies the interaction between different devices, including aspects like concurrency, noise and multi-threading. As a result, the student sees this subject as not necessary, and difficult, easily loosing his interest in the matter. This document is a summary of the work developed in an undergraduate course, where Wireless Sensor Networks (WSN) based on Sun SPOTs have been used to improve the comprehension and interest of the students. In the undergraduate course Network and Communications, a Game based lab has been developed. The results show the improvements from previous years.**

Network protocols; Wireless Sensor Networks; Game based learning

I. Introduction

Computer networks is an interdisciplinary subject that covers fields between electronic engineering and computer engineering. It is the base of our actual communication systems, going from the telephone, to the Internet, and, in a more subtle way, modern digital TV.

It is commonly assumed that network protocols are integrated in the Operating System (OS). They are seen as a commodity, as the OS itself[1]. The result is a student not too much interested in learning its implementation. Moreover, network protocols usually imply multithreading and concurrency, which are seen as complex by many students. Summing up, the students usually are not too motivated in the subject.

An experience has been made on the undergraduate subject "Networks and Communications" (NC). This subject includes a lab, whose objective has been implementing a small protocol with a basic stack, including:

- Frame definition
- Addressing
- Error control through an Automatic Repeat Request (ARQ)[2] mechanism

The definition of an ARQ implies the development of a sender and reception buffer, the control of the frame sequences, and the use of timers to detect possible timeouts.

Initially, the protocol was designed using an RS-232 null-modem physical layer. The introduction of noise and errors had to be made artificially by the professor. As a result, the students saw the protocols as an overreacting solution to an improbable problem. We wondered if our lab was a turn-off[3]. For this reason, since 2005, we have started to use Wireless Sensor Networks (WSN), with the objective to improve the students understanding and motivation regarding the subject.

The WSN alternative has been confirmed by an increasing number of experiences as an educational tool. Some use them as a tool for other purposes, like a system for kids to browse Internet[4] or for undergraduates to control the environment[5]. Others use them to teach network protocols [6]-[10], as is our case. In this work we present our experience in this field.

II. Networks and Communications

Networks and Communications is an introductory course to the network protocols. It is the first time in their curriculum that the students see the characteristics of a network and its protocols. The base of the subject is the OSI reference model, the main local and wide area network protocols, and the TCP/IP stack.

A. OSI Reference Model

There are different ways to approach to the networks (bottom-up[11], top-down [12]…), but the base is usually the Open Systems Interconnection (OSI) basic reference model [13] from the International Organization for Standardization (ISO). It defines seven different layers, which are stacked. Every layer provides services to the upper layers and is client of the lower one. The layers are:

- Application: Provides access to the OSI stack.
- Presentation: Gives the representation of the data transferred between the applications.
- Session: Its purpose is to provide means to organize and synchronize the dialog and manage the data exchange.
- Transport: Transfers data transparently, relieving the upper layers from any concern with the detailed way in which reliable and cost effective transfer of data is achieved.

- Network: Provides routing and relay solutions to the transport layer.
- Data Link: Provides means to transfer data over a specific physical layer.
- Physical: Defines the way the bits are transmitted through a medium. It usually implies the definition of connectors and cables, antennas… depending on the kind of transmission.

Taking into account the real implementations, sometimes the OSI stack is divided in three environments, considering the layers interaction [14]:

- The network environment: includes the lower three layers, and it is dependent on the characteristics of the network itself (medium, codification, format…). The interaction is between layers of adjacent nodes.
- The OSI environment: its services are more oriented to the applications. The four higher layers compose it. The communication in this case is between the layers at the end of the communication.
- The Real Systems environment: are the applications itself (browsers, word processors, terminals…).

A representation of both, the OSI reference model stack and the associated environments are shown in Figure 1.

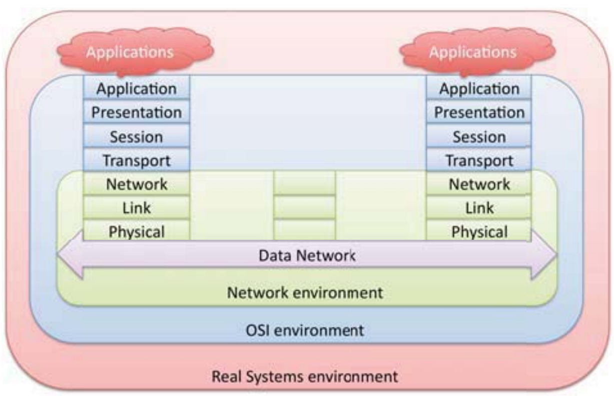

Figure 1. OSI reference model and associated environments.

The Networks and Communications subject (NC) is oriented to the network environment, with a brief vision of the OSI environment.

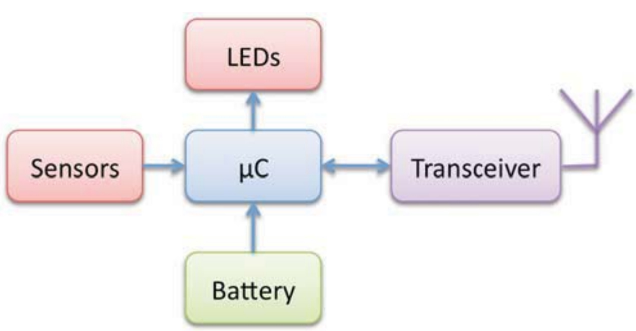

Figure 2. Block diagram of a basic WSN node.

B. *Wireless Sensor Networks*

WSN is a relatively new technology, which is based on the improvements of wireless communications, low power consumption and sensor size reduction. The results have been devices the size of 2 AA batteries, able to get information from their environment. Every device becomes a node of a network that allows transmitting data among them [15]. The block diagram of a basic device is shown in Figure 2.

The simplest WSN node includes a microcontroller, a transceiver and a battery. Usually it also includes some sensors and depending on the application, LEDs or other display to provide some information to the user. Initially the communication was using proprietary transceivers. Since 2003, the IEEE 802.15.4[16] protocol is available for this kind of networks.

IEEE 802.15.4 is a simple protocol, designed to work with little resources and power[17]. It uses three different bands, but the most common is the ISM 2.45 GHz band. This band is shared with Bluetooth and Wi-Fi, meaning that it has to include strategies to avoid interferences with these and other protocols. This is accomplished using an offset quadrature phase-shift keying (O-QPSK) modulation.

One of the first solutions for WSN was the TinyOS framework[18]. It provides a language (NesC), an Operating System (TinyOS) and the blueprints for different devices. One of the firsts commercially available was the tMote(Figure 3.). These motes were based on a Texas Instruments (TI) msp430 microcontroller. It also included an IEEE 802.15.4 transceiver from Chipcon (now TI), and some sensors and LEDs to get data and provide some feedback.

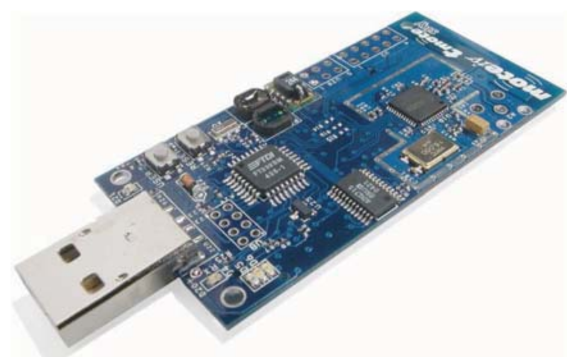

Figure 3. tMote photograph.

This alternative seemed interesting as more nodes could be included in the network, and no cable was necessary. For this reason, we started in 2004 to work with these devices. The organization of the labs was:

- Introduction to NesC programming.
- Introduction to the tMote sensors.
- Interchange of data between motes.
- Development a simple weather station based on the tMotes and using an ARQ protocol to transfer data between them.

The main difficulty was the change of point of view. When a student implements a program, usually thinks in solving a problem with an algorithm, easy and simple. He is the only user, and he knows how to work with it. As a result, the program works perfectly. In other words, if the algorithm is good, the results are warranted.

In computer networks, the situation is different. The algorithm can be perfect, but if errors are not taken into account, the system will work with bad performance, or simply it will not work. This implies that the student has to start to think about the inputs and outputs as something that can introduce errors. These errors have to be detected to take the necessary actions.

Using an RS-232 cable, this concepts where hidden as the communication was nearly ideal. With WSN the students started thinking for an ideal environment, more or less equivalent to an RS-232 cable. However, the situation was fully different. The networking concepts appeared naturally. Frames from one group were received by another (addressing), or some frames were lost when two motes transmitted data at the same time (collisions).

Another major issue was the difficulty of the students to learn the NesC language. Although it is similar to Java (the base language in Computer Engineering), it took between 10 to 14 hours to learn it, which was half the laboratory time. This time could not be easily reduced because there was not a simple simulator to continue the work at home, as TOSSIM[19] was not a good educational tool.

In any case, the difference between the use of an RS-232 cable and this tMotes was clear. Only the possibility to light a LED changed the face of the students. The lab results were better, but we continued to think about possible improvements.

Figure 4. Sun SPOT photograph.

C. *Sun SPOTs*

In 2004 Sun Microsystems started to work on a WSN device including an IEEE 802.15.4 transceiver and an embedded Java Virtual Machine. The devices were finally available in Europe in 2007. They created a grant for universities to use these devices in labs. This way we started to work with them.

A Sun SPOT (Figure 4.) is a device similar to a tMote, but more fancy. The first difference is its box, made of transparent plastic, which allows seeing the electronics. It includes sensors for acceleration, temperature, humidity and switches. It also includes eight tri-color LEDs, to provide information to the user. Last, but not least, it has a microcontroller with enough memory to run an embedded Java Virtual Machine.

From our point of view, the main improvements were:

- The platform is based on the Java programming language. This means that the students do not have to learn a new language, just a small API.
- There are more sensors and LEDs available, which allows more interaction with the device. The students see these devices like toys, and their interaction as a game.
- An Integrated Development Environment based on Netbeans, which simplifies the code development.
- A “console output” is available, which can display messages.
- Finally, a simpler simulator[21] has been developed, which allows the students to continue the work at home, without being necessary to have the device itself.

The result was an increase of the lab available time. For this reason, we started to think about new alternatives to improve the labs taking into account this increase of resources, and some requirements:

- The objective of the lab had to be an application, not a protocol
- The protocol had to become a tool to solve the applications requirements
- The target had to be adequate to the time available for the subject.

With these conditions in mind, we thought that the best objective was to develop a small game based on two Sun SPOTs.

D. *Laboratory modules*

The lab is organized in four modules and one presentation of results. The students are organized in groups of three people. We have chosen three to have at least two students of the group in the lab, as sometimes one has a “job emergency”. The exercises are solved as a group, but the documentation is presented individually. The modules are based on the tutorials and documentation from Sun Microsystems[22]. These modules are:

1) *First steps using a Sun SPOT (1 session)*

The purpose of this module is to introduce the student to the Sun SPOTs. Taking into account that we want the student to have the IDE and simulator installed at home, we explain them how to do it in the class.

After that, they learn how to update the Software Development Kit (SDK) and the Sun SPOTs. This task has to be done every year, as new stable tools are available.

Finally, they start to use the IDE to develop a simple demo application that blinks a led. The students usually end up feeling that the labs can be done.

2) Sun SPOTs anatomy (1.5 sessions)

The objective of this module is to introduce the different elements of the Sun SPOT to the students. They start to use the tri-color LEDs making counters and sliders to present the information.

The second step is to use the buttons to get information from the user. The students have to develop a program that changes the LEDs behavior depending on the buttons.

The third is to use the accelerometer, and then the fun is guarantied, as they see a quick feedback to their movements. They have to show the angle in the three axes on the LEDs. As a result, they see that it is not possible to get the horizontal angle using and accelerometer.

Finally, they start to work with the radio just measuring communication strength. They can see that if they separate the modules, the power is reduced. This experience also allows explaining the physics behind the transmission of data.

3) Sun SPOTs communication (1.5 sessions)

This module was the introduction to the way a Sun SPOT communicates. The difficulty of this lab is not the code itself, but the problems that the students have due to the concurrency of different devices sending information at the same time. As said before, in a few minutes the students perceive the need of addressing and error control.

4) Sun SPOTs game (8 sessions)

The last module is a small project. They have to design and develop the game that is the objective of the labs. For this purpose, they have to propose a game that can be developed using two Sun SPOTs that communicate. The action and results have to be shown with the LEDs. The students can use any sensor in the device. Examples of these games are:

- Bowling: The movements of the hand and arm are measured, when one button is pushed on a Sun SPOT. This is equivalent to throw the ball. Depending on the angle and acceleration, more pins are knocked down in the second Sun SPOT.
- Shake master: Two players have to shake as fast as possible two Sun SPOTs. The one that shakes the Sun SPOT quicker wins.
- Power master: Two players make the quickest movement that they can. The one that gets the highest acceleration wins.

From this small sample, it is easy to see that the preferred sensor is the acceleration one. The reason is the quick feedback that it provides. However, sometimes, the response is not as fast as desired.

All the games require interchange of data. This implies that they require developing some kind of network protocol, including an ARQ mechanism. Although the IEEE 802.15.4 provides an acknowledge mechanism, it is not used in the lab. This way, the students could define their own frames and its behavior.

The students also understand the frame control field and its contents. The required flags come from the functionality. They also, become conscious of the necessity of a sequence number to have a reliable link.

The main drawback was that some student relied on the simulator, which has an ideal behavior. This means that no noise is created. In this case, these students were unable to interchange data. A workaround was to include a node that sent random data. This created network noise, providing a more realistic scenario.

5) Presentation (1 session)

Finally, there is a session where students present their games, showing their behavior. Usually their focus is on the application itself, forgetting about the communication aspects of the project. For this reason, the evaluator has to ask questions regarding the protocol implemented and how they solve different problems.

The approaches presented by the students from the application point of view, can be classified as:

- Basic Client-Server: There are two different programs, one for every Sun SPOT. One behaves as client and a second as server. The start-up sequence has to be followed precisely, or the system is unable to run.
- Advance Client-Server: The Sun SPOT include both programs, the client and the server, and at the start-up sequence, the protocol defines which Sun SPOTs behaves as server.

At link level, the addressing implementation is necessary as explained before. Reliability is achieved through the implementation of an inactive ARQ mechanism. The main difference with standard protocols is the text-based codification of the fields. Only a minority of groups does the leap to binary codification.

Finally, all the students present the documentation of the project. It is also difficult for them to differentiate between the documentation of the project and the comments of the code. The difference between the application, and its elements, description and the way it has been implemented. In some cases because they have relied on their partners, in others, because they really do not know how to explain what they have done.

To minimize the problem, the outline of the documentation is explained in detail at the latest session. This solution has proven to be effective, improving the documentation quality.

E. Results

The marks of the students for the last five years have been analyzed. The graph shows on one hand the percentage of students that passed the lab; on the other, the rate of students that passed over the number of students that went to the first exam (Figure 5.).

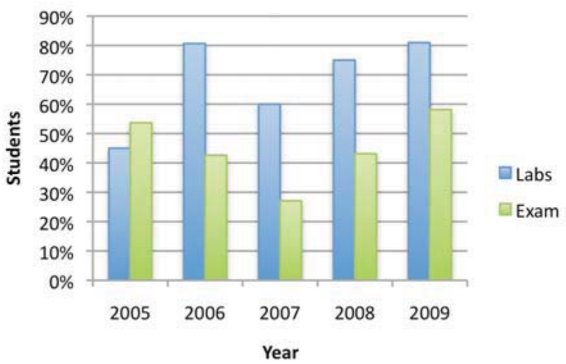

Figure 5. Percentage of succesful students in the lab and the first exam.

From the percentage of successful students, it is possible to see that there is an important change between 2005 and the rest of the years. The main reason is the change from an RS-232 based lab to a WSN one.

In January 2006 we started to use WSN in the lab. The number of students that pass the lab has its first maximum. The only drawback is a decrease of students that pass the exam. We thought this change came from the increase of difficulty of the labs, making the students change their priority from networks to learning NesC.

The number of successful students descended in the labs and the exam in January 2007. One reason was still the difficulty to learn and program NesC. Another reason was the motivation. There is a subject the same period that included the development of an application. The time required was high, and was seen as more interesting for them than WSN. At this moment, we started to think about a new change.

In January 2008 the results improved a little, although they were still worse than 2006 ones. This confirmed us that we had to rethink this laboratory.

In January 2009, with the introduction of the Sun SPOTs, both labs and the exams have had a maximum.

With the new labs, the students seem more motivated, asking more questions. A questionnaire has been done in December 2009 to confirm the last information (Figure 6.).

Questionnaire

1. How well did the introductory modules prepare you for the laboratory?
2. Did you find the SunSpots installation clear enough?
3. The SunSpot anatomy module provides enough information?
4. Did you find the SunSpots communication module appropriate?
5. Do you think a game is a good application?
6. The organization of the laboratory in a small project is a good option for this subject?
7. Do you think that the lab with SunSpots is interesting?
8. Did the laboratory help you to better understand the subject?
9. Do you think that this laboratory has to continue?
10. Summing up, do you think that this laboratory has been useful?
11. Comments

Figure 6. SunSpot laboratory questionnarie.

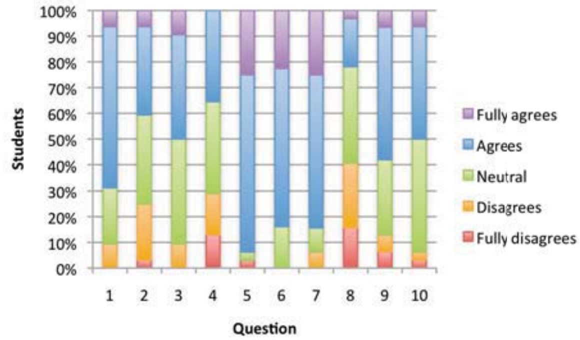

Figure 7. Questionaire results

The plot (Figure 7.) shows the results for the last cohort. In general, the students agree or fully agree on the actual organization of the laboratory. Only in questions 2, 4, 8 and 10 the agreement is below a 50%. Theses questions are analyzed deeply:

- Question 2: The installation of the SunSpots is difficult in shared environments like those that are used in a lab. Every year we have found problems with this. We are working to solve them.
- Question 4: This communications module presents how to program the SunSpots communication. To work with this module, it is necessary to understand communications and threads. From the comments, it seems that the problems come from the use of threads, so we are modifying the actual module with an extensive introduction on threads.
- Question 8: From the results of this question it seems that the laboratory is a failure, although it cannot be so bad if they think it has to continue (question 9). From our point of view, the problem is that the labs have been too centered on the game development. To solve this we will increase the stress on protocol aspects.
- Question 10: The sum is good; around a 50% see the laboratory useful, and less than a 5% disagrees. We think the alternatives presented will increase the quality of the subject, improving the number of agrees.

In summary, the use of SunSpots and WSN has proven to be a good tool to teach network protocols. However, the impact of related aspects, like the programming language or threads, has to be well calibrated.

III. Discussion

The results obtained with this lab can be qualified as good. The students have shown a deeper understanding of the subject. However, we have made a deeper analysis to evaluate pros and cons:

Pros:

- The students see the Sun SPOTs as a toy, which is easy to understand and use. This reduces the concerns for a new technology.

- The developing tools are free which is an important issue in an education environment[8].
- The use of Java has minimized the time required to learn. This has allowed focusing on the subject aspects.
- The use of a game as a target in NC has introduced network protocol as a tool, not as a requirement. This has improved the perception of the students.
- The students have shown, in general, creativity and motivation.

Cons:

- The students sometimes where more interested on the game image than its functionality, increasing unnecessarily the work, resulting in unsatisfactory outcomes[9].
- Sun SPOTs IDE does not include an easy debugging tool. This implies solving problems through console messages, which is not always easy.
- It is necessary to improve the interaction between theory, problems and labs in NC. A high percentage of students fail the course, although they have passed the labs.

Many of these results are shared by [7], which also uses Sun SPOTs to teach sensor networks.

IV. CONCLUSSIONS

The introduction of WSN on NC has introduced an improvement on the learning process of students. Now they see networks as a tool and not as commodity. It has also improved the number of students that have passed the lab. The students' learning curve is steeper, giving more time to focus on the subject aspects. They have also presented a stronger interest in the network related concepts, and better understanding. Finally, it is necessary to improve the integration between the theory, problems and labs to increase the number of successful students.

V. FUTURE WORK

These results have been used to redefine this subject in the new Computer Engineering Grade, based on the European Space for Higher Education (Bologna Declaration)[23]. Now, we are preparing the material for this new course, based on the results.

ACKNOWLEDGMENT

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An Interdisciplinary Practical Course on the Application of Grid Computing

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***Abstract*—This article gives an overview of the organization and realization of an interdisciplinary practical course on grid computing. Both the lecturers and the attendees came from diverse backgrounds and disciplines including computer science, physics, medicine, and the humanities. We describe the management of the course, the assignments, the infrastructure developed and experienced in this interdisciplinary practical course at the University of Göttingen. The challenges and issues, the benefits, the expectations and their fulfillment are discussed. The experiences of the course show that diverse disciplines can be brought together to convey the benefits of grid technology by experiencing varied grid applications in production-like grid environments.**

***Keywords*-grid computing, interdisciplinary, practical course, D-Grid**

I. INTRODUCTION

The idea of an interdisciplinary practical course in grid computing emerged from an overlap of interests in the disciplines computer science, physics, medicine, and the humanities. Grid computing, an important research area in computer science, connects and advances research of disciplines with high computational demands, such as the participating ones.

A grid is a networked system “that coordinates resources that are not subject to centralized control using standard, open, general-purpose protocols and interfaces to deliver nontrivial qualities of service” [1]. It provides a service-oriented environment for collaborative and efficient sharing of computing and storage resources belonging to different organizations to fulfill the demand of distributed, high-performance applications, in our context grid applications. Today, grid applications are commonly used in research, as well as business domains such as financial, automotive, and pharmaceutical domains. However, the requirements of such applications grow steadily and need to be fulfilled by an appropriate infrastructure such as provided by a grid.

In this practical course, concepts and usage of grid computing in an interdisciplinary manner were taught. The expertise of the German grid initiative D-Grid [2] provided an excellent basis for studying and learning about grid technology. The students experienced and applied production-like grid environments. The D-Grid initiative is a research program initiated and funded by the *German Federal Ministry of Education and Research* (BMBF) to establish a national grid infrastructure for research and industry. The community projects of the D-Grid initiative involved in this course included MediGRID [3], *High Energy Physics* (HEP) Grid [4], and TextGrid [5]. These are all related to the disciplines mentioned above and located in Göttingen within the joint grid resource center GoeGrid [6].

The course took place in the summer term of 2008 at the University of Göttingen. The participants were assigned uniformly to groups according to their field of studies . Each discipline provided a tutor for supervising the students. For the establishment of a local grid environment, several computers located in a local computer network were allocated to each group.

The concepts of grid technologies were explained by practical applications of a grid environment using the grid software Instant-Grid [7]. Instant-Grid contains all necessary software to automatically set-up a pre-configured grid on computers in a local network by booting from CD. Within such an environment, the students were able to start, build, and use an experimental grid system for solving the assignments of the different disciplines.

This article is structured as follows: In Section II, the structure and content of the assignments of the three disciplines are explained. Afterwards in Section III, we describe the technical environment that the students used to solve the assignments. In Section IV, we present the evaluation of the described course. In Section V, we consider related work. Finally, we conclude with results and an outlook in Section VI.

II. Course Description

The goal of the course was to teach the concepts of grid computing by the application of grid computing independently of the field of study of each participant. In this section, the course and the posed assignments are described.

A. General Structure

The assignments addressed the HEP Grid of physics, the MediGRID of medicine, and the TextGrid of the humanities. All assignments involve inevitable concepts of computer science.

Each discipline developed a track of assignments, where each of the tracks referred to the corresponding D-Grid project. The students worked on the assignments on a rotational basis. The tracks of the assignments were structured in:

1) introduction and fundamentals,
2) exercises and practice, and
3) reflection and further discussions.

In part one of each track, the students prepared a report about the respective discipline that included the applications of grid computing in the fields of the discipline, their requirements, and the status of the related D-Grid project. During the preparation, the students looked into the specifics of the discipline and established connections between the discipline and grid technology. Furthermore, the students made suggestions and developed proposals for an optimization of the project with a focus on the grid perspective.

In part two, the students realized the ideas suggested in part one and solved practical assignments. This included the establishment of a production-like grid environment based on Instant-Grid and the technical realization of the assignments. Depending on the assignments, the students needed to discover, use, and start appropriate grid services and functionalities provided by *Globus Toolkit 4* (GT4) [8] or by the respective D-Grid project grid environment. With the help of these services, the students were able to develop efficient solutions for the assignments.

The assets of the solutions, as well as further optimization proposals were discussed and reflected in part three. At the end of each track, the developed grid software was presented and executed. The presentation included the design and challenges of the development, issues, and proposals regarding the existing solutions of the projects. These were then discussed and reconsidered. This also led to an improvement of the solutions presented by the students.

At the end of the course, the students compared the requirements and solutions between the three tracks. They reflected upon similarities and differences, but also expressed specific criticism and their opinions whether they would use grid technology for other areas.

B. Learning Objectives

The goals of the course can be divided into two areas – one related to technical knowledge about grid computing and, the other – to soft skills. The goals related to technical knowledge included understanding, explaining, and applying grid computing technology, in particular:

- concepts of grids,
- requirements of grids especially related to different disciplines,
- application and usage of grid technology on areas in different disciplines based on D-Grid projects,
- migration of legacy applications into a grid environment, and
- experiencing advantages of grid computing.

The goals related to soft skills on the other hand focused on the students' abilities to communicate clearly in the context of a wide range of topics, such as:

- collaboration across disciplines,
- establishment of effective and manageable team work in a heterogeneous environment,
- discussing results in a clear, structured, and concise manner,
- critical thinking,
- gathering and accessing relevant information from a library and other information resources,
- explaining the scientific method including the concepts of hypothesis and experimental controls, and why objectivity is essential, and
- writing effectively in an appropriate style and depth,
- integration and application of knowledge and experiences.

These learning objectives were promoted in several ways. These included team meetings with the instructors of the respective discipline, introductions to the disciplines, grid concepts, and available grid services. Furthermore, weekly assignments and tutorials of the grid used in the respective D-Grid projects were given. These activities were extended by regularly discussions, and final presentations.

C. D-Grid Projects Located in Göttingen

The D-Grid projects located in Göttingen supported by several faculties of the University of Göttingen built the basis for the assignments. The projects are described in the following.

1) MediGRID: The MediGRID project uses grid computing systems as an underlying infrastructure for providing services that access distributed applications supporting biomedical research, clinical research, and image processing.

These applications require high-performance computing and may access data from geographically distributed locations. The project represents institutions in the area of medicine, biomedical informatics, and life sciences. The objective was the development of a grid middleware integration platform enabling biomedical life science services. For this, four methodological modules (middleware, ontology, resource fusion, and e-Science) have been developed and served for the establishment of a grid infrastructure implementing the specific requirements of biomedical users [9]. Therefore, the grid middleware has been embedded in a user-friendly environment that allows intuitive access to e-Science services for biomedicine. Applications for image processing, ontology, and biomedical informatics are incorporated in a web based portal [10] that is easily accessible and usable. The services that access these application are based on an enhanced security model with different security levels. This is required because access to specific secured resources which host pseudonymized patient data is needed for the computation of medical data, e.g. for investigations on specific disease patterns [11].

A major requirement in up-to-date biomedical research is the creation, maintenance and usage of data located in shared resources. In MediGRID, this need is fulfilled by grid services provided in the e-Science platform that is continuously available. Within this platform, costs for the usage of resources for necessary tasks are pre-calculated and policies are established to allow a reliable deployment. Data can be stored and processed by using grid services independently of the geographical location. MediGRID demonstrates the feasibility and usefulness of grid services in medicine and life sciences by applying these services in biomedical research with multidimensional data and by correlating genotypic and phenotypic data.

2) HEP Grid: The D-Grid initiative supports the world wide *Large Hadron Collider* (LHC) [12] computing grid of the *High Energy Physics* (HEP) community. The LHC is a proton-proton collider at CERN in Geneva, Switzerland, where multi-purpose experiments – *A Toroidal LHC ApparatuS* (ATLAS) [13] and *Compact Muon Solenoid* (CMS) [14], – and two specialized experiments – LHCb [15] and Alice [16] – are performed. The computing challenges of these experiments are enormous. For example, the ATLAS experiment produces data in the order of 300 MB/s. This data needs to be reconstructed, i.e., the signals of the various detector components are combined to reconstruct the particles that are produced or scattered in the collision of protons. The demand on storage and computing resources can only be handled with modern grid systems.

Different kind of grid applications exists in the HEP community. Scientists all over the world access the experiment-data to perform a variety of physics analyses. This data is replicated to grid sites all over the world to avoid data loss. However, individual analysis jobs can also be very data or computing intensive. Thus they may need to be switched to another data location. In addition, detector components need to be calibrated regularly. The calibration jobs take detailed measured data as input and are performed on remote grid sites.

A large fraction of the grid jobs calculate simulated collision events, so-called Monte Carlo events. For a physics analysis, simulated and measured data of roughly the same size are required. Monte Carlo events are continuously produced to increase the available statistics. Similar to the measured data, the calculated Monte Carlo event-results are distributed on the grid for world wide access.

3) TextGrid: TextGrid is the humanities project in the D-Grid initiative. It establishes a trusted repository (TextGridRep) that ensures the long-term availability, interoperability and re-usability of research data in the humanities. Furthermore, TextGrid provides a platform for the co-development and sharing of dedicated services.

The humanities are a large and diverse discipline. TextGrid's first dedicated target group within the humanities are philologists, linguists, musicologists, and art historians. For these scholarly fields, TextGrid provides a virtual research environment (TextGridLab) that offers a single point of entry to specialized tools, content, and collaborative spaces.

The TextGrid infrastructure is based on the grid middleware GT4 with extensions along several lines to meet the requirements of research areas in arts and humanities. First of all, TextGrid developed a gateway between *Grid Security Infrastructure* (GSI)-based security – which is prevalent in grid environments – and Shibboleth [17] – prevalent in higher education. Another major effort was the integration of repository technologies for data and metadata management [18] solving problems of long term data preservation. On higher architectural layers, TextGrid creates an open service environment and provides a grid-based, interactive client based on the Eclipse Rich Client Platform [19].

D. Assignments of the Disciplines

In the following, the tracks according to the D-Grid project are described corresponding to the structure presented previously.

1) MediGRID track: Within this track taught by the biomedical informatics group, a brief and practical introduction to different biomedical applications in the MediGRID web portal was given. The participants used and experienced applications for medical image processing, bioinformatics, and clinical research in the MediGRID portal. Before using these applications, the students needed to be authenticated. For this purpose, they acquired X.509 certificates belonging to the *Virtual Organization* (VO) "Education" from the German D-Grid Initiative that was established especially for this course and for later teaching purposes. After applying this certificate to the MediGRID portal, the participants were authorized to use protected medical grid resources and to execute selected grid applications of the MediGRID portlets [11].

In part two of the MediGRID track, application programs from the production grid portal, such as image processing (3D ultra sound), bioinformatics (gene prediction) and clinical research (biosignal processing), as well as an identification portlet (as a Java deployment service) were gridified and added to the Instant-Grid environment. The distribution into the grid was carried out by command-line instructions. These commands were transferred into a shell script and started on available computing resources. The sequence of commands in this script corresponds to a grid workflow. A workflow is an abstraction of complex processes in the grid software stack. This script was exemplified by gridifying a gene prediction algorithm for the comparison of two species. The developed workflow was applied in the Instant-Grid environment and reflected the same operations that would have been stated on resources in the grid offered by MediGRID. The results of solutions and adjustments developed by the participants were taken into consideration in ongoing MediGRID developments.

In the third part, the discussions and reflections focused on issues about ensuring privacy of hardware and software resources. These included topic such as security requirements in application classes related to privacy levels compared to existing security measurements. Specific aspects as the need of certificates, and the procedure of applicable and operable security levels (security vs. usability) were considered. Finally, it was discussed which requirements future medical grid applications need to fulfill, and how ethical aspects and the acceptance of the end user need to be considered. The result was a report that has been presented for discussion in the MediGRID community at the university.

2) HEP Grid track: The goal of this track was to give insights on typical demands of computing required by modern particle physics experiments and to study the various challenges posed. The DØ experiment [20] at the Tevatron, a proton-antiproton collider at the Fermi National Accelerator Laboratory [21] in the USA was taken as an example. At the Tevatron, packets of protons and anti-protons collide at their highest possible energy at a rate of 2.5 MHz. After an online event pre-selection, the signals of the scattered and newly produced particles are recorded by the DØ detector at a rate of 50 Hz. The average size raw data of a single event is 250 KB. The experiment runs since 2001 so that already an enormous amount of data has been stored. From the raw data, physic objects are reconstructed and stored to further process them in various analyses.

In the first part of this track, the simulation of DØ events was performed step by step. The workflow of the simulation chain and the workflow scripting system were investigated in detail. From the duration of the simulation of single events and the file size of the different output data, the demand on computing and storage resources of the whole experiment was extrapolated. As an example, in 2005 the DØ experiment reprocessed 250 TB of raw data. Such enormous challenges for computing can only be handled with grid clusters distributed world-wide.

In the second part of the HEP Grid track, the interactive simulation of Monte Carlo data was adopted in such a grid environment. This has been accomplished by the use of Instant-Grid, similar to other tracks of the lab course. The students submitted simulation jobs to the Instant-Grid environment via commands provided by GT4. The use of a command line interface and scripts or macros is the typical way of applying grid computing in high energy physics. In addition, an supplementary introduction to gLite was given. GLite is the grid middleware of choice in the HEP Grid.

The third part included reflections and discussions of various grid applications addressed in HEP. Aspects like data archiving, data security and safety, data management, the structure of a grid system, demands on the middleware, and possible future developments were discussed. The students' conclusions were that grid computing has permanently been used for the production and storing of physic experiments and Monte Carlo data. For the calculation and analyses of the data, a stable, standardized, and tested grid environment is more important than the application of the latest features of grid technologies.

The computing challenges of experiments at the LHC at CERN in Switzerland increase the need of grid computing in high energy physics even more. As an outlook, the requirements of the Fermilab and the CERN experiments were compared.

3) TextGrid track: Building on the experiences of the D-Grid humanities project TextGrid, this track provided students with an overview of the opportunities of the e-Infrastructure used in the humanities. The first part of the track introduced exemplary research activities in the humanities including research on languages, literature, and art history, covering their diverse scholarly workflows [22]. Building on these information, the students derived requirements for grid technologies posed by the humanities. Amongst the scenarios mentioned by students were collaborative and interactive workflows, as well as data curation – the preservation, interoperability, and re-usability of digital objects. Particularly, the replication of data across multiple grid nodes potentially raises the stability and availability of data over long periods of time.

In the second part, students practiced how grid technologies support data curation. For an assignment, students replicated digitizations of ancient texts to distributed grid nodes using standard grid protocols. Further extending this exercise, the replicated data were processed at the distributed nodes with a typical function of data curation: the migration of digital objects between formats of varying quality or stability, e.g. proprietary formats versus standard formats with public format specifications. In particular, students were asked to take the digitize high-quality preservation formats (100 megabyte TIFF images without compression) and convert them into a scaled-down copy for presentation purposes (1 megabyte JPEG2000 format) making best use of distributed processing in the storage grid.

The discussions in the third part of the track reflected the opportunities of grid technologies for the arts and humanities. During the discussions, the perspective reverted, and students highlighted possible contributions of the humanities to current e-Infrastructure technologies. This includes existing mechanisms for data curation such as repository technologies that establish reference networks of data (cf. data-centric science [23]), as well as virtual research environments that foster collaboration through exchange of data and methodologies. Discussions about the integration of such systems into existing e-Infrastructure environments helped students to understand the opportunities and limitations in both worlds.

III. Technical Configuration

The practical realization of the course assignments required grid software. We chose Instant-Grid since it offers simplified possibilities for starting local computer grids and its software components are compatible with the ones utilized by D-Grid. Instant-Grid employs the open source grid middleware GT4 and is based on a Knoppix-Linux [24] environment. With the GT4, Instant-Grid provides a preconfigured security infrastructure and services for job management, data handling, and information delivery. With the Instant-Grid Live-CD, a computer grid can be started without a complex installation. This environment allowed the students to study and use a grid on their own computers without the restrictions that are associated with a remote production grid environment. However, starting many Instant-Grids on the same local computer network requires specific adjustments, as described in this section.

A. *Configuration in an Existing Local Network*

Instant-Grid was originally designed for closed *Local Area Network*s (LANs) in order to avoid conflicts with services, such as *Dynamic Host Configuration Protocol* (DHCP) services that run in the existing network. Thus, starting many Instant-Grids on the same local computer network is not possible without further adjustments. Therefore, the computers used for the course and required to boot Instant-Grid had to be separated from the lab network. For this purpose, we established layer three networks on a layer two switch to which the computers were connected. We grouped the computers of one Instant-Grid into different *Virtual Local Area Network*s (VLANs) on the switch-level and separated them from the local computer network (lab network).

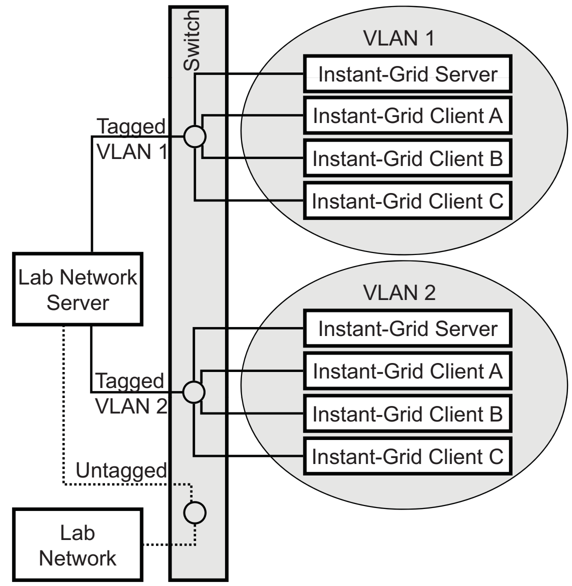

Figure 1: VLAN configuration

Figure 1 illustrates two project groups, VLAN 1 and VLAN 2, in which each starts an Instant-Grid server with up to three clients independently from the other project group. The packages sent out from the Instant-Grid networks were labeled (“tagged”) with the identifier of the VLAN, and filtered by a firewall to provide protection for the existing networks, and to route between the different virtual networks. The packages sent from the other networks, such as the lab network, did not have any labels (“untagged”), and thus were not filtered.

In our configuration, four computers from the lab network were configured and then assigned to each group. The students were able to start and configure their own grid on these computers. However, this was only possible at predetermined times, since the particular network configuration of VLANs had to be enabled by a course mentor. After the students finished their activities in their local grid, the network switch needed to be reset to the original configuration. This was necessary because of security reasons that require that only the standard operating system is started.

To access the Internet from the Instant-Grid network, *Network Address Translation* (NAT) had to be set up on the Instant-Grid server as well as on the router of lab network, i.e., on the lab network server. Figure 2 illustrates the NAT-gateways of our configuration.

B. *Technical Challenges of Instant-Grid*

Instant-Grid is based on Knoppix-Linux. Because of its Live-CD design, neither a component for the management of user accounts was provided, nor a configuration could be written permanently. Therefore, it was not feasible to create permanent grid user accounts. Grid user accounts have additional but very specific requirements according to

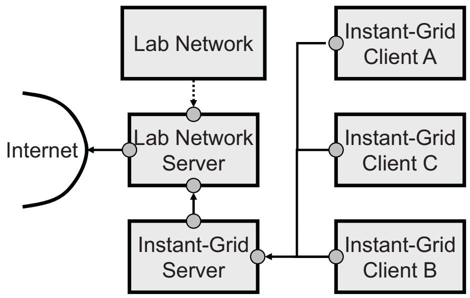

Figure 2: NAT configuration

TABLE I. FIELD OF STUDY OF THE PARTICIPANT

Computer Science	Physics	Medicine	Humanities
5	4	5	2

the grid environment compared with a usual Linux user account. The students were only able to work locally and, in addition, they needed to be supervised by a mentor, since misconfiguration of the network had to be avoided.

Instant-Grid requires a closed local network. Therefore, as described in the previous section, the integration of Instant-Grid into an existing network setup is a laborious task.

Students should not be able to make changes in the network configuration of a lab network server or set up the VLANs. In our setup, a script was started by a mentor, which then activated or deactivated the VLANs. If Instant-Grid had been started without configuring the VLAN, it could have caused serious conflicts within the lab network.

IV. EMPIRICAL COURSE EVALUATION

A. Course Workload

Due to organizational reasons, this practical course has been restricted to 16 participants. 16 students with heterogeneous backgrounds and training attended the course. The distribution of the fields of study of the participants is shown in Table I. The number of participants studying in the humanities was adequate. While the "digital humanities" are gaining speed in applying computer science technologies in their research, awareness about digital infrastructures such as grid technologies, as well as the adaptation of infrastructure technologies to the requirements of the humanities still remains to be increased.

B. Student Perceptions

Overall, the course has been evaluated as "good". The results of an anonymous feedback survey are summarized in Table II. They reflect the differences in the knowledge and the background of the participants. While students of technical studies missed details about programming, other students were overwhelmed by the technical detail. At the end of the survey, the students were able to make comments. One student mentioned that "it is preferable to work on the

TABLE II. PARTICIPANTS FEEDBACK SUMMARY

Assertion	Average	Median	Standard deviation
The course was excellent	3,43	4	0,73
The requirements of the course were too high	2,14	2	0,83
The dimension of the course was too big	2,57	2	1,29
At any time, I fulfilled the required premises of the course	3,71	4	0,77
Relevant content could be differentiated from irrellvant content	2,57	2	1,06
The contents of teaching were demonstrated by examples and viewings	3,57	4	0,72
Difficult terms have been clarified during the course	3,29	3	0,6
The used media (blackboard, beamer, etc) were appropriate for the course	4,14	4	0,61
The assignments were structured in an excellent manner	2,43	2	1,18
The speed of the course was too slow	2,57	3	0,73
The noise level during the course was very distracting	1,43	1	0,73
Questions were answered during the course.	4,86	5	0,33
Before the course, my interest of the topic was very high	4,14	5	0,92
After the course, my interest of the topic was very high	3,71	4	1,08
Cross-references to other lectures were recognizable	2,86	2	0,78
The benefit for a later employment is very high	2,57	2	1,06
The lecturers showed high professional competence	4,43	4	0,33
The lecturers presented the content of teaching in an excellent manner	3,29	3	0,7
I would recommend the lecturers to fellow students	3,57	4	0,72

Legend:
1 to 5 scale: 1 - "strongly disagree", 5 - "strongly agree"

assignments individually", and that "the assignments could include complex programming". Another student wrote that "it was interesting to know about financial and legal issues of grids". However, others mentioned the opposite. The foundations need to be taught at once and not repeatedly in the beginning of each track. Afterwards, the individual requirements of each discipline for grid and their differences can be imparted so that the student can learn to apply similar methods in different areas.

C. Tutor Perceptions

In this practical course, each of the three disciplines provided tutors for supervising the students. However, the interdisciplinary manner of the course required more collaboration between colleagues and students than in other usual courses of the disciplines. The preparation of the course took longer, because the different teaching methods and expectations of the different disciplines had to be evaluated, understood, and synchronized first. The tutors as well as the students had varying knowledge of the other disciplines and thus required proper introductions to the disciplines. Even technical terms for the same concepts of grid computing may vary. Also, it was necessary to get familiar with the technical environment chosen for the course so that the right tasks could be defined for the students.

Overall, the feedback given by the involved tutors showed that they had to dedicate more resources for preparing and supervising the course, but they also earned special competence for later teaching purposes.

V. Related Work

Several courses about grid computing have been taught at other universities. The courses focus mainly advanced computer science students. These include courses described in [25], or [26]. In contrast, Mache and Apon describe a course for undergraduate students only focusing on the computer science course of study [27]. They present five knowledge areas that should be covered by a grid computing course. This includes appropriate topics and exercises. Similar approaches of courses for undergraduate computer science students can be found in [28], or [29]. A top-down teaching approach is described in [30]. This means that the students begin with job submissions using a grid portal and, afterwards, they experience step-by-step the details of a grid computing infrastructure and its architecture.

The research projects and disciplines mentioned in this article offer in addition to the practical grid course an interdisciplinary seminary about grid computing in the winter term at the University of Göttingen. This lays the foundations for the students that attend the practical course about grid computing.

Our practical course aimed at students from diverse fields of study including physics, medicine and the humanities. They had to learn best practices from each field and its relation to grid computing. To our knowledge, this interdisciplinary approach of teaching grid computing is unique.

VI. Conclusion

The interdisciplinary practical course on the application of grid computing has been evaluated as "good" by the students and thus can be considers a success. Overall, the course provided students with diverse perspectives on grid computing from the various disciplines involved – physics, medicine, computer science, as well as the humanities. From scholarly requirements to hands-on experiences, as well as discussions about the current state and the possible future of e-Infrastructure research. The distinct perspectives contributed to the precipitous learning curve of the students during the practical course.

For solving the assignments, the students had to learn to apply their knowledge on other disciplines, but also to explain their field of study to students of other fields of study, for example, for the realization of inter-domain software. Grid computing builds a bridge between different backgrounds offering innovative opportunities and promising ideas in each discipline. The students had to solve the assignments by combining advantages of each discipline through developing, applying, and experiencing different solutions. The students learned to propagate their ideas and to communicate problems as it was best for the interdisciplinary solution and furthermore, to realize their ideas in a grid computing environment using available resources most efficiently.

In the final discussion and post-processing of this interdisciplinary course, the interactions and teamwork between the students of the different fields of study were considered. The goal of the course was not that the humanities students have to program or that the computer scientist learns the processes of the genetic prediction, but that they work in a complementary manner and solve the assignments together in a team. Ideally, the physicist, for example, would ask the correct questions, the humanities student would introduce methods for answering the questions, the physician would contribute with background knowledge, and the computer scientist would developed a technical solution. In each track, the adequate roles were taken by the students and, therefore, the tracks could be solved in an complementary manner.

From the technical side, Instant-Grid has been proven as an ideal tool for the realization of the course. Instant-Grid is an adjustable and scalable instrument for ad-hoc grid applications. For short-term development, extensions such as specific portals and even complete development environments can be included.

Following the character of this practical course, solutions have been elicited to solve the assignments of the disciplines. For imparting knowledge of grid programming expertise, especially for computer science students, Instant-Grid is the tool of choice. We experienced that there is a great demand for grid-developers in the IT sector, but also in other sectors. However, conveying techniques of grid programming to students in an interdisciplinary course is not feasible, because students who do not study computer science get lost in the technical details. The computer science students were responsible for technical requests of the fellow students and for the realization of their solutions. However, a practical course about programming in a grid has been offered in addition in rotation with the course on the application of grid computing.

At the University of Göttingen, the grid computing teaching track is well established. Good evaluation results and several successful applications for future grants underpin the stability of Göttingen's grid infrastructure and emphasize the need for substantial grid teaching to educate junior assistants.

For the interdisciplinary course described in this article, we plan to extend or exchange assignment tracks. For example, other fields of research that are active in Göttingen can be considered. This could include a track about quality assurance in grid computing [31], a track about numerical simulations in a grid environment, cf. OptiNum-Grid [32], or a track about legal issues [33]. Ideally, a training framework for the application of grid computing technology, as well as for programming grid services should be developed.

The skills that were taught in this course went far beyond the technical ones of applying grid computing. It was about collaboration with colleagues, who introduced different knowledge and who may solve tasks in a different way. It was about communication, in which requirements and proposals are not explained only with technical terms and concepts that are only understandable for people of the same discipline. The participants got deep insights in each discipline and learned to develop solutions in cooperation with students from other disciplines as it is often the case in the professional world, where the disciplines often melt. Acquiring such skills is a life-time experience for the students, as it can only be conveyed in an interdisciplinary course.

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Introducing Scenario Based Learning

Experiences from an Undergraduate Electronic and Electrical Engineering course.

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Abstract— **The aim of this work is to introduce scenarios into the first and second year of our undergraduate electronic and electrical engineering curriculum to improve the educational and learning experience of our students and in doing so improve the quality of our graduates. This paper introduces the curriculum development involved in the implementation of scenarios. We reflect upon and analyze the successful aspects of this trial and identify those areas that are in need of improvement.**

Keywords – Student centred learning, scenario-based-learning

I. Introduction

The UCL Electronic and Electrical Engineering (EEE) Department, in which this study is based, runs two undergraduate programmes: a three year BEng and a four year MEng. We aim to produce graduates who have a strong theoretical grounding in the fundamentals of the discipline, are capable of independent thought, able to approach new problems, can communicate results to others in a logical way and work in a collaborative environment.

Both students and academic staff have expressed a number of concerns with the undergraduate program which is largely delivered by lectures, tutorials and expository laboratory classes. Students find that the course is not as hands-on as they expect and don't appreciate the depth of theoretical background required to fully engage with the discipline. Academic staff are concerned that student motivation and performance has decreased by the time they get to the second year.

In an attempt to address some of these problems, we introduced a series of, week long, engineering design projects called scenarios, where students work in small groups in a realistic situation on a fairly open problem where the outcomes are undetermined. The scenarios are designed to draw on and consolidate the lecture material that the students will have received in the preceding weeks. As such, planning of the course and design of the scenario needs to be carried out in an integrated fashion with emphasis on horizontal integration across lecture courses and application of knowledge through engineering design projects (scenarios). The use of a series of short focused scenarios in the first and second year, rather than the more often used design project running over an entire academic term in parallel with lectures, was designed to: enable a greater range of areas within the curriculum to be covered, simplify time management for the students, and provide increased opportunity to provide formative feedback that the students can apply in upcoming scenarios.

Here we present the pedagogical rational for such an approach and describe the implementation of scenarios. The observations of the staff involved and the student evaluations for a selection of the scenarios obtained after the first year of this trial are presented and analyzed. The successful and unsuccessful aspects of the first year of this trial are identified and improvements are proposed.

II. Background and Pedagogical Context

This work was initiated by the pilot study of Mitchell et al. who used problem based learning (PBL) to teach an entire 3rd year electrical engineering module that was traditionally taught using conventional lectures [1]. The student feedback from this trial was overwhelming positive, however, one of the issues with this trial was getting the students to adapt and acclimatize to this new learning style, especially after two years of conventional lectures. As such this optional course now has a relatively low take-up rate. Here we wanted to build on the success of this trial and expose some of the benefits of the PBL methodology to our students at an earlier stage when they are more receptive to new approaches. In fact a number of them have already experienced such techniques in their secondary education.

Scenario based learning (SBL), Project based learning (PjBL), and Problem based learning are subsets of a larger class of learning techniques broadly know as enquiry based learning [2]. These learning techniques all emphasise a student centred approach where the students take ownership of their learning and are active participants in the process. They all require the students to develop the research skills and methodologies that are associated with the particular discipline. The role of the academic changes from that of the 'oracle' dispensing knowledge to that of a 'facilitator' whose role is to guide and support the students in their own learning.

At one end of the spectrum is problem based learning where 'the problem', which generally has a predetermined outcome, is used to direct the students to both acquire and assimilate the necessary knowledge in the process of solving it. In PBL the solution may be less important than the new knowledge gained during the process. At the other end of the spectrum is Project based learning, where 'the problem' is more open ended and the focus is on the application and assimilation of previously acquired knowledge, in the development of a solution. Project based learning is very focused on the production of an end product. Scenario based learning lies somewhere in the middle of this spectrum and different scenarios may be more 'problem' or 'project' like. The word scenario is used to denote several distinctive aspects of this learning mechanism.

Firstly, the scenario is seen as an integrated part of the entire course structure and not a mechanism for delivering an entire module as in PBL. Scenario based learning aims to get the students to draw on the experience, knowledge and skills that they have already acquired or been exposed to in lectures and laboratories across the entire course and apply this to a scenario that has not previously been encountered. This also means that the traditional lecture course element, albeit modified, remains. This eases the concerns of sceptical academics and is in line with research that suggests that PBL is no better at delivering knowledge than lectures [3].

Secondly, the scenario is designed to place the students in a realistic situation, where the problem is fairly open and as such the outcomes are undetermined. In this sense scenario based learning draws inspiration from the experiential model [4] and the situated cognition [5] theories of learning. The experiential model emphasizes the need for concrete experience in the learning cycle as Kolb conceived it, that is, the experience that comes with actively participating in and solving a problem. Situated learning stresses the importance of placing learning in realistic and authentic contexts. It draws particularly heavily on the apprenticeships model [6] where students learn on the job under the guidance of colleagues and a mentor. The social aspects of learning are also emphasised in situated learning. This is the learning that arises from interaction with and observation of other team members. This has a particular resonance with a discipline such as engineering, which until relatively recently, before becoming an academic discipline, was taught solely in this manner and where practitioners predominately work in teams.

Flora and Cooper found that students achieved the best results when they are taken on a journey starting initially with expository experiments where instructions are provided and the outcome known, followed by a more PBL type experiment, where the outcome is known but process is designed by the students, and then are finally given the opportunity to experience a PjBL design project [7]. The course structure, proposed here, with lectures, expository laboratories, and several scenarios, that employ elements from both PBL and PjBL, attempts to produce such a learning environment.

III. Scenario Design and Implementation

For the first trial of this program in the 2008-09 academic year we were able to run three scenarios in the first year and two scenarios in the second year, as summarised in Table 1. Unfortunately we were not able to restructure the lecture courses to deliver to the scenarios, however, in order to mitigate this we designed the scenarios to align to the current course structure as much as was practical.

TABLE I. Summary of trialed scenarios.

Title	Description
Scenario A: Electromagnetic lifting	Redesign an electromagnet to maximize the lifting force using only a single battery.
Scenario B: Java based image coding for airport security.	Develop a piece of software in java to scramble and descramble passenger images using a secret key.
Scenario C: The Transistor Radio Kit	Design and build a radio that could be assembled by hand in a third world country and powered off the grid.
Scenario X: Call Detection System	Design, build and test a system that is able to non-intrusively acquire the signal from a phone line and determine the number that has been dialled.
Scenario Y: Due Diligence Report on Broadband Access Solutions	Research, assess and compare the performance, practicality and economic implications of three potential next generation broadband access technologies.

The scenarios were run as group projects with 4-5 students in each group. Group projects allow the students to develop team working and management skills that employers value highly. They also provide an environment for collaborative learning where group members are able to learn off each other [3]. In addition group projects and reports makes running these

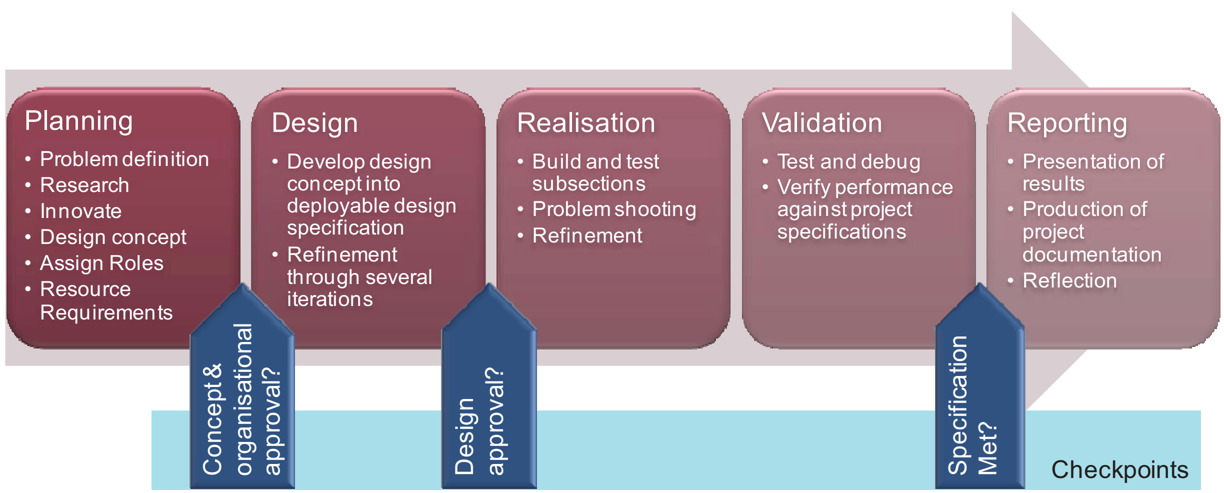

Figure 1. Generalised Scenario project model.

projects practical and reduces the marking load. The groups were changed for each scenario to ensure that individual students did not feel overly penalised by being in a group that they perceived as poor.

Each scenario was run over a week, during which there were no lectures and thus they could concentrate solely on the scenario. The students were presented with a problem on Monday morning and were given until the following Monday morning to submit the final deliverable. The scenario structure and timeline was based around the project model, shown in Fig. 1, which was adapted from Svensson et al. [8] to suit a week long project. In particular checkpoints (or milestones) were introduced to ensure that the students were making appropriate progress, to encourage particular types of activities such as brainstorming and to provide formative feedback.

IV. Assessment and feedback

One of the aims of introducing scenarios was to bring alternative forms of assessment and increased opportunities for feedback into the undergraduate program. Increasing the diversity in assessment helps to reduce the reliance on unseen examinations as the primary assessment mechanism and provides a more diverse range of situations in which the students can demonstrate their mastery of the subject [9]. The scenarios use both formative and summative forms of assessment that are intended to guide and enhance the students learning process and ensure that feedback is an integral part of the process.

Each scenario used a slightly different method of summative assessment ranging from individual or group based technical reports, oral or poster based presentations, through to critical review and comparison of another group's technical approach with that of their own. The type of assessment was chosen to be as authentic as possible and thus contribute to the realism of the scenario. For example, in Scenario Y, the summative assessment was based on a presentation of the group's findings and recommendations, and submission of a due diligence report to the board of the fictional company that had commissioned the research study. In addition for each scenario the students had to submit an individual reflective commentary.

For each of the reports the students were given a report template (MS word) that contained the suggested report structure and a marking grid. The marking grid was closely aligned with the published assessment criteria. Further guidance was also given in terms of the purpose of each section, the elements it should contain and the aspects that should be explained or described. Again, these are clearly linked to the assessment criteria given to the students. The group/individual reports and the reflective commentaries were submitted online as MS word documents using "Moodle". The submitted reports were downloaded, marked and then uploaded back into Moodle, completely electronically, to minimize the turnaround time and thus provide timely feedback. Feedback was provided using the comment function in MS word inserted where relevant in the report. The embedded marking grid was used to provide additional comments specific to the assessment criteria and to give an overall assessment of the report.

In addition to the summative assessment, formative assessment was also used throughout the week by introducing checkpoints into the scenario week schedule. These checkpoints were used by the facilitators to monitor progress and provide feedback to the groups. Generally there would be two checkpoints one early in the week (either Monday or Tuesday) to ensure that the group had organised themselves and one later. The first checkpoint took the form of a short discussion with the group in which the group would present the current state of the design plans and their approach for achieving those plans. This included ensuring that the group had put in place an organisational structure i.e. group leader, had assigned tasks to each group member and had developed a time plan for the week. This first checkpoint also often occurred at an important decision point, where the group needed to justify a choice to the facilitator in order to progress to the next stage, e.g. in Scenario A the students needed to justify their choice of battery and wire gauge to the facilitator before they were given the wire to construct the coil.

The second checkpoint (generally on Thursday afternoon) involved presentation or demonstration of the group's solution to the scenario. To make this more interesting/motivating for the students this was often arranged as a competition in which all groups were present e.g. who could lift the heaviest weight in scenario A or the first to recover the unknown phone number and call the unknown phone it in scenario X. However, the results of these competitions did not contribute in any way to the grade that the students received. In addition to the excitement and motivation that the element of competition provides the exposure to the solutions of the other groups and the comments provided by the facilitators at these sessions provides feedback which can be incorporated into the final report. This is particularly evident in the presentation session of Scenario Y, where the other groups who are the audience get to see the work of their colleagues and the questions/suggestions that are provided by the board/facilitators, as well as question the presenters themselves.

All scenarios made use of 1-2 page reflective commentaries in which the students were asked to:

- Comment on or give details of their own input into the design process and summative tasks.
- Reflect on a personally significant aspect of the task.
- Identify and critically evaluate those aspects of the scenario that they consider successful and those that were less successful. Suggest how things might be improved in subsequent scenarios.

The purpose of the reflective commentaries was twofold firstly, and rather bluntly, they provided a mechanism for assessing the input and contribution of the individual students to the group based scenario. Secondly, and more importantly they get the students to reflect on and analyze those aspects of the process that worked well and those that didn't and to take these thoughts forward to improve their own performance in the subsequent scenarios. In addition, the commentaries provide a wealth of feedback with respect to what the students liked about the scenario, what their concerns where and what aspects of the scenario design they thought worked well.

V. Student Evaluation

Student evaluation of the scenarios was obtained in a range of ways the first and most immediate form of feedback came from informal chats, during and after the scenario, with tutorial groups and various students in the departmental corridors. The general feeling from these was that we had certainly developed something that they found enjoyable and challenging, however, there were a number of concerns expressed over effective group working strategies and fairness of awarded grade based on group work. Common responses included:

"We had one group member who barely turned up and when we tried to assign him/her a task it was not completed so someone else had to do it making it hard to complete the task. Will this penalise the other group members?"

"I hope I get a better group next time."

After each scenario the students were asked to complete a simple online feedback to the following questions:

1. What aspect(s) did you like most about this scenario?
2. What aspect(s) did you not like about this scenario?
3. What would you change to improve this scenario?

The analysis and presentation of the findings, from this style of questionnaire, is somewhat more challenging due to the unconstrained nature of the responses. Common themes in the responses to each question have been identified and scored based on the number of occurrences normalised to the total number of respondents. To get an overall feeling for whether the feedback was generally positive or negative, and what areas worked well and those that needed improving the categories identified in the 'like', 'change' and 'dislike' responses are plotted against the frequency of response to each of the identified themes. A negative value is assigned to 'change' and 'dislike' comments to indicate that this is an area that needs to be improved in future and give way of visualising whether the feedback is generally positive or negative.

VI. Case Studies

A. Scenario A: Electromagnetic lifting

This scenario aims to enhance the learning of basic concepts from electro-magnetics, circuit analysis, and mathematics. Students are required to design and build an electro-magnetic system to see which team can lift the heaviest weight. At the end of the week an Olympic weightlifting style competition is was held to test the designs.

One of the difficulties and major question raised by staff with running a practical scenario, such as this, where the students are expected to construct something is: 'Can you achieve something that is realisable, draws on the taught material and is sufficiently challenging within a week?' In order to make this scenario practical to run in a week the design was constrained by restricting the mechanical design of the electromagnet and limiting the choice of battery to either a 9V PP3 or a 1.5V C battery. The students were provided with a wide range of possible wire gauges to wind the coil with. These restrictions whilst constraining the possible solutions somewhat meant that by the Thursday afternoon when the testing competition was due to take place all groups had produced an electromagnet.

This scenario is essentially an optimization problem where the students need to determine and apply appropriate theory to produce a mathematical model of the system. They need to use both, tabulated and experimentally determined parameters in the model, and make various assumptions. The optimum solution, determined from the model, is then constructed and tested. In this case the optimum solution involves choosing the optimum wire gauge and battery.

In order to ensure that the students applied their theoretical knowledge to this problem and didn't just use trial and error experimentation a checkpoint was used on Tuesday. The students had to justify their choice of wire gauge and battery based on their theoretical calculations. They were then given their chosen wire and battery. This worked particularly well as all groups produced a theoretical model showing an optimal solution. Interestingly, at this checkpoint most were not convinced that it was possible to lift the weight that their models predicted (in the range of 40-80 kg) and were quite surprised when the best group lifted 53kg on the competition day. This observation highlights the importance of giving students the opportunity to apply and test theory.

The findings from the student evaluation of this scenario are illustrated in Fig. 2.

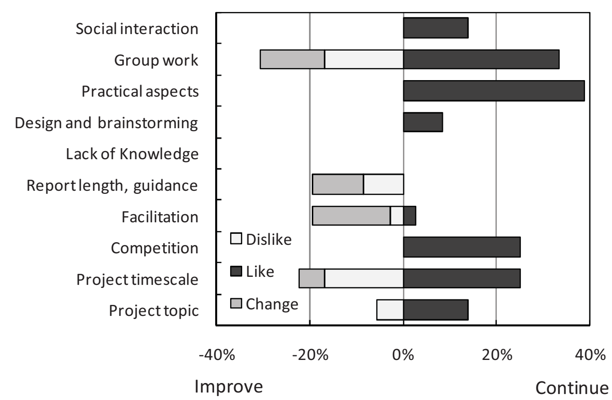

Figure 2. Scenario A: student response rate by theme (Total responses = 36).

Immediately we see that the feedback is generally more positive than negative. Surprisingly, given earlier comments, the students particularly valued the group work and social interaction involved with this. The 'dislike' and 'change' group work comments were related to issues arising with poor co-ordination between group members leading to a breakdown in efficient group working, or trouble with group members who did not contribute. The design, practical application and competition elements of this scenario were unanimously liked. As this was their first university project report students expressed some apprehension towards what and how much was required. They did not seem to appreciate the close alignment between the provided report structure, associated marking grid and assessment criteria. The students were fairly neutral on the quality of the facilitation that they received from the academics and would prefer to have more rather than less facilitation.

Generally the students were happy with the one week timescale and focusing solely on the project for the week, however, some students felt it could have been slightly longer.

B. Scenario B: Software development for identity recognition in an airport security system in Java

This scenario involved writing a program to apply mathematical transformations to an image in order to first scramble the image and then descramble the image. This scenario was designed to build on the mathematics and programming modules. Before commencing this scenario the students had completed their first year programming module in Java. The scenario requires the application of two main skills: algorithm development and programming. The first stage, algorithm development, requires the students to turn the problem statement into a series of commands that a computer can execute. This involves working out a method that can be used to apply the mathematical concepts such as rotation to an image that is constructed of pixels. The second stage, programming, requires the students to convert the algorithm into a formal programming language, in this case Java.

Algorithm development is a very generic skill that is fundamental to most problem solving tasks, however, in the context of computer programming it often gets entwined in the syntax of the programming language, which results in confusion amongst students. To reduce this confusion a checkpoint was used to break the week into two parts. On Monday and Tuesday each group of students was given a working space with a white board and it was suggested that they did not begin programming until after the Tuesday afternoon checkpoint. At the checkpoint the groups needed to explain, to the facilitators, their high level project design showing how the various parts of the program would work together and describe the algorithms that they had developed to implement each part.

The student evaluation, shown in Fig. 3, of this scenario indicates that the project topic was liked and the students enjoyed the group work. The main issue with group work was the fairness of work allocation and reward for actual contribution to the project. More worryingly are the comments related to a lack of prior knowledge. However, within the scenario week most groups produced a working solution which tends to suggest that the scenario was pitched at the right level and they did in fact have sufficient knowledge to complete the task.

In this scenario, unbeknown to the students, the groups were engineered to have at least one strong programmer, based on the assignment results from the programming course. This strategy was chosen to maximize the potential for collaborative learning especially for the weaker programmers. Student feedback from their reflective commentaries indicates that this was particularly successful for developing the programming skills of the weaker programmers, and the team management skills of the stronger programmers as the following comments indicate.

Comment from strong student.

"As I do have previous programming experience I did my best to explain algorithms, object oriented programming, Java and general programming basics to the team members. It was a rewarding teaching experience, as most team members did understand my explanations and learnt from them."

Comments from weaker students.

"During the course of the scenario, I had the opportunity to learn from my group members as I approached them for help whenever I was stuck on a task."

"Once the Scenario B teams were announced, I instantly felt relieved. I was never good at programming to begin with and there in my group is 'student A', a good programmer and someone who really can get the job done. I now have a new insight into programming as I did not realise simple codes are enough to program something I presume as difficult."

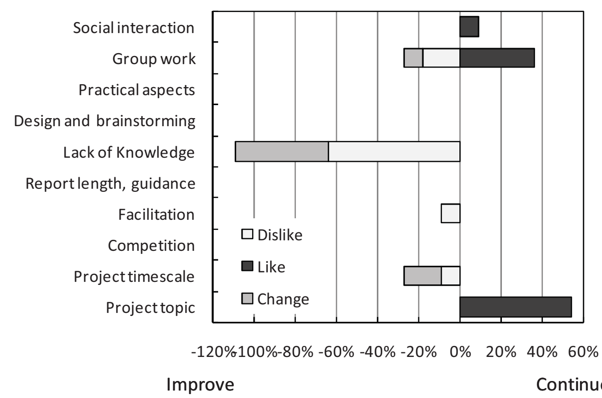

Figure 3. Scenario B: student response rate by theme (Total responses = 11). Note, the same categories used in figure 2 are used here for comparision.

However this did result in some issues with work load distribution and input into the project, with the more capable team members contributing far more. This scenario was designed to have elements suitable for the weaker students, more challenging elements for the stronger students. The problem with this is that the stronger students often perceive their contribution as been more significant to the project. To improve on this the testing of the software solutions will be designed to be more incremental, so that weaker groups will be able to meet some of the specifications and stronger groups will be challenged by the more advanced specifications. As with the previous scenario a few students would have liked it to be slightly longer.

C. Scenario Y: Due Diligence Report on Broadband Access Solutions

This scenario was introduced to the second year students in the form of a memo from the board of a company that was commissioning them to carry out a due diligence report on the technological, economic and social merits of three different technological solutions, and to inform the company which solution had the most potential.

This was a paper based study that required the students to use and apply their knowledge from the communications courses, and carryout further research into aspects of each technology. The introductory session included a presentation from an industrial expert who gave the students an overview of the problem and introduced some of the regulatory, economic and social issues involved in this problem.

The thought behind the design of this scenario was to give the students a free range and as such there were only two formal contact and evaluation sessions planned for the week as well as submission of a final group report. The first was an informal chat with each group on Tuesday afternoon at which they had been instructed to describe how they had organised themselves in terms of dividing the problem between the group members and their schedule for the week. The second was a 12 minute presentation to the board on the Thursday afternoon, where the board asked fairly challenging questions. There were also one hour facilitation sessions if the students wished to avail themselves of them on Monday afternoon, Tuesday and Thursday morning, however, few made use of these.

During the running of this scenario a number of things were learnt. Firstly, it was a observed that during the presentation from the industrial expert the students still appeared somewhat shell shocked by the task that had just been introduced and weren't altogether sure what they were meant to do or what relevance this presentation necessarily had to the task. Thus at the end of the presentation they did not ask many questions and as such did not make the best use of the opportunity.

Secondly, the Tuesday afternoon check point was intended to ensure that the students had thought about the issues involved and got themselves sufficiently organised to be able to meet the Thursday afternoon presentation deadline. Ideally they should have as a group developed a framework with which to analyze and compare the three company's technologies. In practice by this stage most of the groups had simply divided the tasks four ways using the obvious split of tasks, i.e. each company, and the social and economic impacts, as set out in the memo. This meant that rather than working as a team towards a common goal, they tended to immediately split the tasks and then retreat into their own silos to research and write their own sections of the presentation and final report. As a consequence both the presentation and the final group reports tended to be somewhat disjointed rather than a coherent piece of work that lead to a single conclusion. Thus in this project it is important that each group works together to create a well structured plan and schedules regular group meetings with all members present.

To ensure that the groups develop such a strategy and work as a team the following changes are planned. The first day will be much more structured. After the introduction the groups will have a group brain storming session before lunch, then the presentation from the industrial expert, a group reassessment session to incorporate what they have learnt from the expert presentation, followed by a formal feedback session with the facilitators. At the Tuesday checkpoint the students need to present the framework and criteria that they plan to use to assess the three solutions, along with a justification of the criteria chosen. This Justification will also be part of the final report.

VII. Conclusions

The trial has shown that it is realistic to complete a practical engineering design project - 'from concept to product', that both excites the students and enhances the material covered in lectures, within a week.

The use of staging and checkpoints throughout the week was particularly successful in guiding and providing feedback so that the students applied the knowledge and theory gained from lectures to the design problems. This was reflected in the quality of the reports, which are actually more important than the actual solution/device produced, far exceeding the expectations of the staff involved in assessing them. It was also reflected in the need to provide more structure in Scenario Y to encourage a more collaborative approach to the assessment of the technologies. Student feedback on the week long project timescale was also generally positive.

The group working aspects of the scenarios were particularly successful, despite the reservations, based around contribution, that come with using group work for summative assessment. The students particularly liked social aspects of this learning process. In particular, it was clear that the weaker students gained enormously by learning from their peers and the stronger ones learnt much about leading a team. Daily group progress meetings will be introduced in future scenarios to encourage a more collaborative approach. Peer assessment for moderation the individual marks will also be introduced to ensure that the credit received more accurately reflects the contributions of the individuals to the team performance.

The student feedback on the scenario topics, practical and design aspects was very positive. Their engagement and participation in the scenario weeks was high with the competitions generating a real excitement amongst the groups.

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Mechatronics E-course for regular students and adults: realization and comparison of efficiency

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Abstract— **This paper describes execution and gained experience with two practically oriented E-courses from mechatronics. Both courses have in common that they include remote experiments and are executed completely online, which is still rarity in the practically oriented engineering education, especially in non-university education. The execution details and educational approach applied in each course were adjusted to two specific target groups. The target groups of a first course 'Control of nonlinear mechanisms' is a group of regular local and regular international students of mechatronics. The target group of second course 'Basics of mechatronics' are employed and unemployed adult professionals from various engineering fields who have already finished their formal education but want to acquire new knowledge. For both courses interactive E-materials and E-tests in Slovene, English and partially also in German language are available within two learning portals, also adjusted to the needs of each target groups. First course was tested with 40 regular students and the second course with the group of 70 adult professionals mostly from industry. While adult professionals appreciated the fact that the course was executed completely online, the regular students have still preferred conventional lectures and especially conventional laboratory exercises over remote ones. Based on the teaching instructor's observances and on the results of anonymous questionnaires, the advantages and disadvantages of the replacement of traditional laboratories with remote laboratories are discussed from a critical point of view.**

Keywords-education; remote laboratory; mechatronics; adult education; vocational training; distant education

I. INTRODUCTION

Until recently the distance education courses for engineers were quite rare, although the distance education is due to its many advantages already quite widespread in other no-engineering disciplines. The main reason for this is that efficient engineering education should include experimental work on real devices, which usually takes place in laboratories and therefore requires personal presence of the learner. This has recently changed with the introduction of distance laboratories that enable remote execution of experiments from anyplace and at anytime [1],[2],[4]-[6],[10],[14]-[17],[19]. However the establishing and maintenance of the remote laboratories is technically very demanding and mostly also costly. Therefore, the practical use of such laboratories in regular education of higher number of learners is still not very common. One of the possibilities to ease the burden of establishing remote laboratories with high number of experiments and courses is to share it between few partners. An example of such shared laboratory is laboratory established within the Leonardo da Vinci EDIPE (E-learning Distance Interactive Practical Education) project [1], [17]. Here the courses are offered by thirteen universities from eleven European countries within the same portal and with some common functionality like booking system. However, beside technical problems, which can be at least partially reduced by sharing of the remote laboratory, there are also many educational problems. Those problems differ according to the target group of learners. In this paper applied educational approach and results will be presented for two courses, each with its own target group.

Both in the paper presented courses aim toward offering practical experience by incorporation of remote experiments. First course was developed within EDIPE project [1], [17], [19] and is intended for education of regular students of mechatronics from eleven European countries. This course 'Control of nonlinear mechanisms' introduces the students to modelling, simulation and motion control design and implementation for nonlinear mechatronic devices. The course was already successfully implemented in the regular education process of 40 local students. Students' feedback was obtained by anonymous survey and is analysed in the paper.

Second course which will be presented and analysed was developed within Leonardo da Vinci MeRLab (Innovative Remote Laboratory in the E-training of Mechatronics) project [9], [12], [13]. Course 'Basics of mechatronics' is designed for employed and unemployed adult professionals who have already finished their official education. This course was tested by the adult participants with very different background knowledge, various levels of official education and also very different interests. Obtained feedback shows that in contrary to the regular students, the adult professionals highly appreciate the possibility to participate in the completely online course as it can be easier fitted in their busy schedule.

The paper is organised as follows. Second section presents course 'Control of nonlinear mechanisms' developed for regular local and international students. Learning portal, course topics, execution of the course with educational approach and students' feedback are described. In third section the course 'Basics of mechatronics' for adult professionals is described. Details about learning portal, topics, educational approach and participants' feedback are given. Fourth section compares the experience of both courses and gives analysis of usability of completely remote engineering courses based on the participants' feedback obtained at the end of both courses. Last section draws some conclusions and presents plans for future work.

II. E-COURSE 'CONTROL OF NONLINEAR MECHANISM' FOR LOCAL AND INTERNATIONAL REGULAR STUDENTS

This course was developed within the EDIPE project as one of the 18 available courses developed in thirteen partners from eleven European countries [1], [17], and [19]. All courses contain high quality documentation with theoretical background for learners and teachers, simulations, various exercises, and remote experiments on real electrical or mechatronic devices and are at disposal to teachers and students of participating universities. Therefore they can be applied as regular courses at the universities. Courses include topics from fundamentals of electrical engineering, power electronics, electrical machines, electro-mechanical and motion control systems. Here presented course 'Control of nonlinear mechanism' deals with modelling and motion control of mechatronic devices with nonlinear dynamics.

A. *Learning portal*

Learning portal named PEMC Weblab, Fig.1, is Moodle based and therefore offers all necessary functionalities for distance learning to the instructor and learners. Basic Moodle platform was completed by very efficient booking system [3] which enables the learner to book time slot for execution of remote experiments in advance and prevents multiple simultaneous accesses to the same experiment. The page of the course 'Control of nonlinear mechanism' is shown in Fig.2.

B. *Course 'Control of nonlinear mechanism' topics*

The 'Control of nonlinear mechanism' course covers an extensive topic of modelling, simulation, planning and practical implementation of the motion control of mechatronic device with nonlinear dynamics. All this is important part of the modern education of electrical engineers, machine engineers and mechatronics engineers.

In the course, all basic elements are included which enable the student with adequate pre-knowledge an insight into the problem, an acquisition of some new knowledge, and practical experience in motion control of mechatronic devices. Beside in PEMC Weblab the course is also available within frame of DSP based remote control laboratory, Fig.3. [3], [7], [8], [11].

Figure 1. PEMC WebLab learning portal, selection fo courses

Learning objectives of the "Control of nonlinear mechanism" course are:

- Modelling of the mechatronic device with the nonlinear dynamics.
- Planning, implementation and optimization of the linear regulator with the cascade structure (cascade P position, PI speed and PI current controller) for the position control of the mechanism with nonlinear dynamics.
- Planning, implementation and optimization of the nonlinear position controller based on the mechanism dynamic model.
- Understanding the reasons for variations in efficiency of the use of linear and nonlinear control methods in the case of nonlinear mechanism control.

As a practical example in the course, the mechatronic device called mechanism with a spring with a DSP-2 control system is used, Fig.4, [3]. The direct current motor shaft is covered with a silicon material and drives the Plexiglas disc. The disc is fastened to the bearing, while on the other side of the bearing the spring is attached. The whole mechanism is fastened on Plexiglas housing. This mechanism is very suited for remote experiments due to its smaller size, no limit and end switches and minimal wear and tear at the long time operation.

C. *Execution of the course*

The first part of the course is intended for familiarization with the theory. Each chapter is also supplemented with an example that represents the use of theory on a practical example. For example, in the chapter dealing with a basic dynamic mechanism model, the dynamic model of the mechanism with a spring is derived and explained. Corresponding MATLAB/Simulink simulation model is also built and tested afterwards. Then, the theory concerning the motion control problem follows, together with the design of suitable controllers and their implementation for the motion control of the mechanism with a spring. After the theoretical part with the simulations, the experiments in the remote laboratory follow.

When ones obtain unsatisfying results, the additional correspondence with tutor or literature study follows. The course flow is schematically shown in Fig. 5.

Figure 2. PEMC WebLab course documentation

Figure 3. Remote laboratory web page

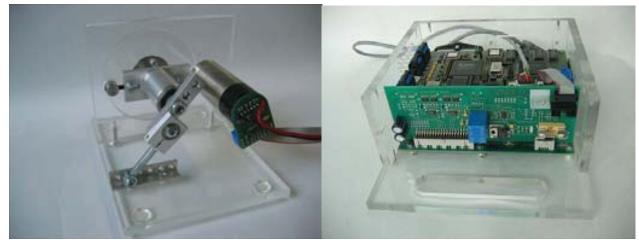

Figure 4. Mechanism and DSP-2 controller

D. Students' feedback

In the course altogether 40 students of mechatronics in two consecutively years were involved. 18 of them have filled anonymous questionnaire which they were handed after conclusion of the course. The feedback was as follows:

- 94% of students think that remote laboratories are a useful addition to ordinary laboratory exercises, while only 22% are of the opinion that remote experiments could entirely replace conventional laboratory exercises supervised by assistant.
- 94% of students are of the opinion that remote experiments are suitable for the strengthening and repetition of knowledge which they have already gained. Further, 72% have the opinion that remote laboratories are suitable also for acquiring completely new knowledge.
- 39% of students performed remote experiments for the first time.
- Despite the fact that remote experiments can be performed independently of the place and time, 61% of the students still prefer executing the experiments in the laboratory to remote experiments, 33% of students could not decide for one option and 6% prefer remote experiments.
- As much as 78% of students have the opinion that they learn more when executing the same experiments in laboratory as when they execute equivalent remote experiments. The rest 22% of students could not decide for one option.

III. E-COURSE 'BASICS OF MECHATRONICS' FOR ADULT PROFESSIONALS

Second E-course which is going to be described in this section is professional mechatronics E-training for employed and unemployed adult professionals from engineering and natural sciences. The emphasis is again put on the practical expertise, since this is the basic need of the participants from this target group. Therefore, the training includes many problem based exercises and high share of the work effort has to be put into execution of remote experiments.

The pilot training was executed with 70 participants from Slovenia in March-April 2009. Additionally the training was executed for small group of 4 participants from Austria. The majority of the participants were workers from the industry.

Also 20 primary and secondary school teachers were participating the training. Around 40% of the participants have finished vocational secondary school, around 25% vocational high school, 20% university study, while the rest provided no data concerning their educational background. Average age of participants was around 45 years. 90% (63) of the participants have successfully finished the training since intensive tutoring has minimized the drop-out rate.

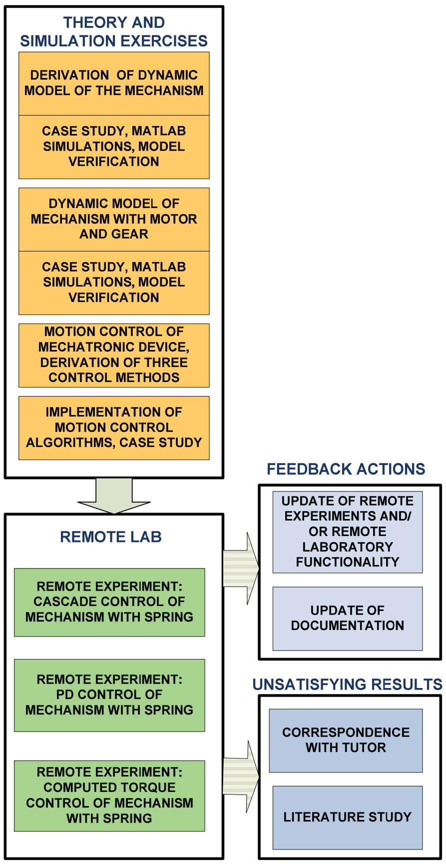

Figure 5. Course flow

A. *Course topics*

The training is composed from four modules; Introduction to mechatronics, Servomotor in mechatronics, Electrical circuits and Mechatronic devices. The whole training requires around 50 hours of intensive work. Each module is given with complete e-materials (in English, Slovene and partially also in German language). Exercises are given for each chapter and there is also an extensive e-test for each module, which is scored. Questions for self-evaluation are given for each unit. Each module also includes remote experiments. The experiments are performed on three devices: two degree SCARA robot, servomotor and circuit with different type of filters including switched capacitor filters, Fig. 6. All experiments are implemented within DSP-2 based remote laboratory [3], [11]. The content of each of the four modules is as follows:

- In the first module 'Introduction to mechatronics', the meaning of the term mechatronics and its short description is given. Then, the historical development from the pure mechanical systems to the state-of-the-art mechatronic devices is described. The structure of mechatronic systems and the role of each element of such a system are also discussed. Required time for the module is about 2 hours.
- In the module 'Servomotor in mechatronics' the role and application of the actuators with motion control in mechatronics is described. Description of the motion control problem and of few frequently used controllers is discussed first. Then, the basic operation principles of direct current motor are presented. Short description of its construction, static characteristics and equations is also given. Finally, the case study of the servomotor is performed trough the remote experiments. Required time for the course modules highly depends on the participant's initial knowledge. However, it is 15 hours on average.
- In the module 'Electrical circuits' first the fundamental elements of electrical circuits, including new fundamental element memristor, are presented. Then AC and DC electrical circuits are briefly described. The frequency characteristics and its graphical presentation in the form of the Bode plot are discussed next. Further filters are presented in the details as one of frequently used electrical circuits in the mechatronics. Emphasis is put on the passive and active low-pass, high-pass and band pass filters. Switched capacitor filters and digital filters are also described. Basic operating principles and frequency characteristics of the filters are studied trough the remote experiments executed on the passive and switched capacitor filters. Required time for the module is 15 hours on average.
- In the last module 'Mechatronic devices', the structure and operation principles of complex mechatronic devices are described. First, mechanical elements, such as the gears, the belts and the joints, are considered. As a simple mechatronic device and building block for more complex devices, a joint drive system is presented. Next, it is shown how joint drives are used to build a robot. The operation principles of the robots are explained in the case study. Finally, the real world problems in the control of complex mechatronic devices are demonstrated by executing the remote experiments with the SCARA robot. Required time is 15 hours on average.

  User front end for the executing the remote experiment with SCARA robot is shown in Fig. 7 (similar are also user front-ends for other experiments). Front end is available in English and Slovene language. The user can choose between three motion controllers and tune the controllers' parameters. Most important signals are shown in the user front end in graphical form. The live picture of the experiment is also transmitted by using Webcam client.

B. *Learning portal*

The e-learning platform implemented in the training is built by using eCampus system developed by a Slovene company B2, [18]. The eCampus is simpler to use then Moodle; therefore it was better choice, since some training participants were not very skilled in working within learning portals. Also visual design of eCampus system is superior to the in Moodle. For MeRLab training the original platform was partially customized to fit the requirements of the training and to enable direct connection to the remote laboratory. Fig. 8 shows the MeRLab Learning web portal [12]. Example of typical learning unit with text, scheme and question for self-assessment can be seen in Fig. 9.

Figure 6. Mechatronic devices for remote experiments

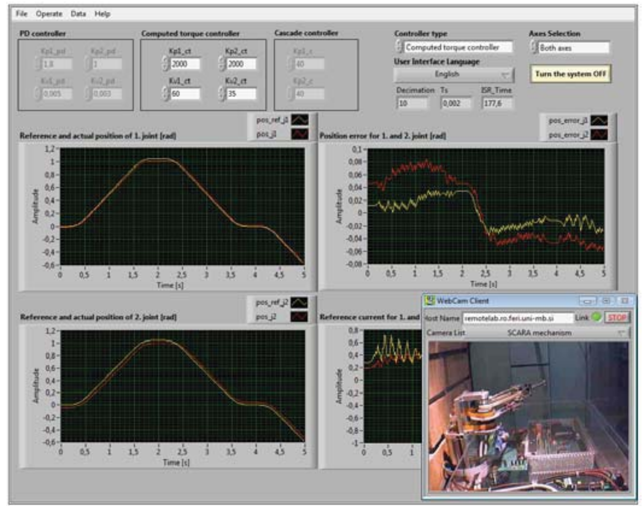

Figure 7. User interface for remote experiment with SCARA robot

C. *Execution of the course*

The training flow is shown in Fig. 10. Before the training one live meeting, about three hours long, was organized with all the participants. During the meeting the participants meet the instructor, have learned how to use learning portal, what will be the training flow and what exact contents of the training are.

Directly after the first meeting the online part of the training has begun. The learners were aimed to self-study the materials and answer questions for self-assessment. After each chapter there was at least one practical exercise which the participants had to solve and send the results to the instructor. The instructor then gave them the feedback about their success, additional aims and instructions for further work. The participants also had to finish assessment test for each module with number of questions from the materials and exercises. The last exercise in each module was remote experiment. The report concerning experiment also had to be send to the instructor. To pass the training, the participants had to complete all the tasks and tests in all modules with at least 50% of success.

During the training, a lot of attention was put to the communication between instructors and participates. Typically the answers to the participants' questions and feedback concerning the solved tasks and remote experiments reports were provided within few hours, while the maximal waiting time was always less than 12 hours. This was most likely also the main reason while the motivation of participants remained high during whole training. Most of the communication was done by sending the personal messages. Also phone communication was encouraged, although the learners didn't use it very much and preferred the communication through the messages. For some participants with weaker knowledge additional live meeting was organized in order to help them at understanding of specially demanding concepts.

The participants were already between the training and especially after the training asked to provide feedback and comments to the materials and training itself. Based on those some additions and improvements of the materials were made already during the training. Formal evaluation was executed at the end of training and lead to the additional changes.

Figure 8. Portal for adult learners

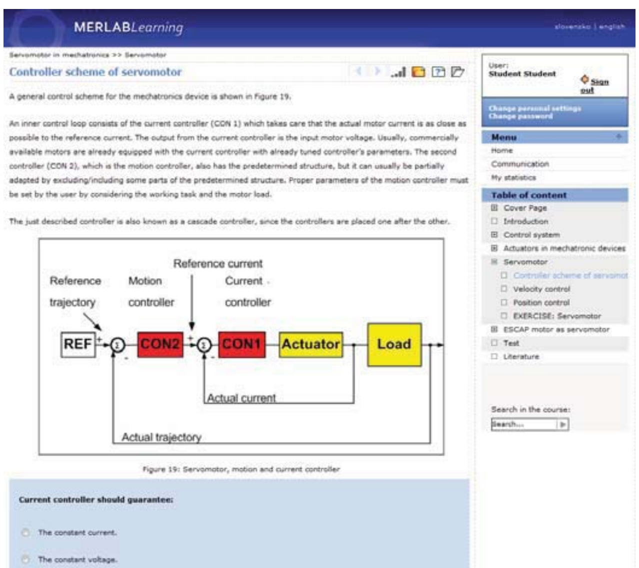

Figure 9. Learning unit

D. Participants' feedback

At the end of each module an evaluation was conducted based on the results of the anonymous survey questionnaire. Since the target group was different as in first course, also questionnaire was adapted. Overall the learners have responded very positively about all aspects of the training. The questionnaire was composed of statements that could be ranked from 1-Strongly disagree to 6-Completely agree. 55 participants took a part in the survey.

Following was found out:

- Almost all participants (92%) have executed remote experiments for the first time. Further, almost everybody have completely agreed (64%) or agreed (23%) with the statement 'I appreciate the possibility to execute remote experiment from anywhere and at anytime.' This really highlights the importance of introduction of the remote labs instead of local labs in the adults' education.
- Then 68% have completely agreed and 23% have agreed with the statements that installation of required software is easy and that the booking systems, as well as user front-ends for remote experiments, are easy to use. From this, it can be concluded that the whole system for execution of remote experiments is user friendly and that learning of how to operate it do not present additional burden for the participants.
- There have been some mixed answers concerning the statement 'Remote experiments were operating without any problems', where only 79% have chosen completely agree, agree and mostly agree, while 21% have disagreed. However this was caused by the antivirus programs and firewalls, which, if present, can block the access to remote experiments. However after those two obstacles were removed, everybody has been able to work with the experiments. The questionnaire's results also show that most of the participants have used the possibility to execute remote experiments for more than once.
- Almost everybody have completely agreed (76%) or agreed (17%) with the statements that the learning portal is clear and well organised and that the contents are clear and concise. Also, over 80% have completely agreed (49%) or agreed (32%) that the gained knowledge will be useful in their further career and that the contents of training correspond to the training goals. Those results are a good indicator that given content is up-to-date and also enough practically oriented.
- The participants have been very positive when valuing the E-training in general. 73% have completely agreed, 20% agreed, 7% mostly agreed with the statement 'I think the whole E-training is excellent'. No one has disagreed. Similar results have also been for the statement 'I will recommend the training to the colleagues and friends.' where 81% have completely agreed, 17% have agreed and 2% have mostly agreed. Again, there has been nobody who has disagreed.

In the free-worded feedback also collected in the survey, the participants have expressed the wish to include even more links and animations into materials. Some commented that they have lacked the time to participate in forum discussion, but overall no greater problems at the training were mentioned.

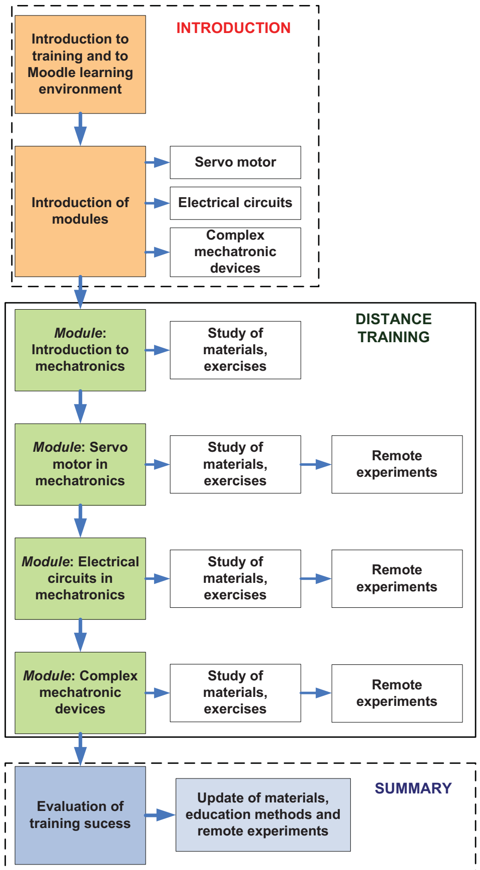

Figure 10. Training flow

IV. COMPARISON OF PARTICIPANTS' FEEDBACK FOR BOTH COURSES

Although the E-learning in both in the paper presented courses was very well accepted by participants, there are still significant differences between two learning groups. In this section we will try to discuss the reasons for difference in obtained feedback.

First, somehow surprising finding was that the majority of regular students (61%) still prefer conventional laboratory exercises over remote one, although they are very accustomed to the use of web. The situation was completely different in the group of adult participants, who have very much appreciated (what is believed to be the main advantage of remote laboratories) the time and place independency that such approach offers. Based on the experience from in-the-lab exercises with local students, the main reason for this might be that most of the students still do not come well prepared to the laboratory. Assistant, who is present in the laboratory, usually helps them with additional explanation. On the other side, at the remote exercises the students have to do everything by themselves and there is no one to provide the immediate feedback concerning the correctness of results. Then, the second reason is still the fact that remote experiments do not cover all aspects of local laboratory work since there is no direct physical contact with the experiment. For example the students do not have to deal with setting up equipment like connecting the cables or performing the measurements by analogue measuring instruments.

Also from instructor's point of view it must be said that the current technology of remote laboratories still do not enable the remote experiments to be equivalently good as the local ones. Therefore it should still be used only as supplement to laboratory exercises (also 94% of students have agreed with that) and in order to strengthen already gained knowledge (again also as 94% of students). However remote exercises are better choice then only simulation at the cases where there is not enough of available laboratory equipment or in other circumstances that make impossible to execute laboratory exercises. Such circumstances were however present in the second target group of employed professionals and in this case remote experiments were really high appreciated.

Concerning the operating specifics of remote laboratory which was used in both courses, both groups had no significant problems. This is a good indicator that booking system, software installation and operation of remote experiments are user friendly and suitable also for unskilled user.

V. CONCLUSION

Remote laboratories are believed to be a good solution in education in the cases when there is not enough available experimental equipment, when the participants have limited time, are distant from laboratory, or they have some kind of physical disability. Also introduction of remote experiments is considered as an optimal exploitation of the available technical resources.

While all this is true to great extent, in the paper described experience shows, that it is still essential to realize what limitations of such an approach has. Working with remote experiments still do not completely equals the laboratory experience, as no direct contact with instrumentation is included. Moreover, the students' answers which were gained via the questionnaire show that although the students find the remote experiments useful and an interesting supplementation of regular laboratory work, there is just a few of those who are of the opinion that such an approach could entirely replace conventional laboratory exercises. Likewise, a great majority of students are of the opinion that they learn more in laboratory than when executing remote experiments.

On the other side, the remote experiments show their usefulness when applied in the education of adults. In this case the time and place independence were much appreciated.

In the paper presented two courses are going to be implemented and regularly updated also in future. The training from basics of mechatronic which was developed for adult professionals is also going to be commercially offered to the companies for the supplementary education of their employees. Therefore, it can be expected that the training will, in the future, at least partially fill the gap between low number of available formally educated mechatronics and high market requirements in Slovenia.

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Distance Practices in Subjects of Automatic Control

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***Abstract*—This work aims at suitably combining hands-on and remote practices in the teaching of automatic control subjects. Virtual and Remote Laboratories in Automatic education have increasingly become a method utilized by universities in their efforts to offer greater schedule flexibility and operation of available resources. This paper discusses the implementation of remote experiments for Automatic Control through both the Distance Laboratory System (SLD), developed at the Universidad Central Marta Abreu de Las Villas, and AulaWeb, developed at the ETSI Industriales of Universidad Politécnica de Madrid.**

The SLD allows users (i) to learn and adjust predefined controllers, (ii) to design new controllers, and (iii) to test and analyze the performance of the predefined/designed controllers over a set of physical devices. The SLD uses MATLAB-Simulink for the distance laboratory, i.e. testing the predefined/designed controllers for practice and the Real Time Workshop Toolbox (RTW) as a real time kernel.

AulaWeb is used as an aid for students and teachers of academic subjects. AulaWeb has been tested at several engineering schools and has been used by over 2000 students each year.

This work shows the results using SLD and AulaWeb in Regulación Automática I of the Universidad Politécnica de Madrid. The distance and virtual practices, made in SLD, are combined with the question in AulaWeb to form Web self-assessment tools.

Keywords- education of control, remote control, remote laboratories, virtual laboratories, innovative education

I. Introduction

Laboratory experiments are an essential part of engineering education. They complement theoretical lectures, as well as illustrate and validate analytical concepts which introduce students to professional practice, social development and teamwork skills in a technical environment [1]. These reasons explain the student's high expectations for laboratory activities.

Simulation tools for training have been popular mainly due to the high cost of maintaining and operating lab equipment. However, despite the advantages – low cost and relatively ease of use – simulators cannot efficiently replicate noise, frequency responses, D/A conversion and other physical phenomena that characterize real systems [2].

The advent of computer technology, particularly the arrival of the Internet, has presented new opportunities to the sharing of expensive software and hardware resources. Consequently, virtual [3] and remote control [4] applications have been developed. These new applications offer the capabilities and flexibilities of simulation tools; while keeping important characteristics of physical systems [5], and distance laboratory applications. Remote experimentation facilities, offered as part of a web-based learning approach, afford a number of critical benefits. For engineering distance education courses, remote facilities constitute the only realistic method of performing many experiments. They allow remotely located students, no longer constrained by time or geographical considerations, complete lab assignments. Thus, it is fair to conclude that remote experimentation facilities enhance the development of skills in the use of real systems and instrumentation [6].

In [7], the authors provide a literature review of modern remote laboratories. In addition, they identify possible evolutions for the next generation of remote laboratories which are under a strong current of evolution. Such labs would no longer be restricted to a single educational topic, where Automatics and Robotics constitute the most frequently used tools.

In the majority of cited remote control experiments, remote users can run an experiment and adjust the process or controller parameters from a set of predefined controllers. This limits the practice to some type of controllers (PI, PID, space of state, etc.).

The Automatic Control Telelab (ACT) enables students to choose a control law, change the control parameters online, and even design their own controller [8]. Our developed Distance Laboratory System (SLD) allows learning and adjusting predefined controllers, designing new controllers, and testing and analyzing the performance of the predefined/designed controllers over a set of physical devices [9].

SLD exhibits some features in common with most distance laboratories in operation at present, such as ease of use, availability and accessibility. Some additional characteristics such as user-friendly and fast user interface, management of multiple requests in parallel form, controller development using MATLAB and Simulink in a remote way and reference change are also added [9]. The SLD incurred in various technological updates aiming to improving its performance and security [10].

AulaWeb [11] is a Web self-assessment tool (WSAT) which serves as an aid for students and teachers of academic subjects. AulaWeb was built by the UPM and has been tested at several engineering schools and used by over 2000 students each year.

The paper shows a suitable combination of hands-on, remote practices, virtual practices and variable questions in the subject of Regulación Automática I at the Universidad Politécnica de Madrid, using SLD and AulaWeb.

This paper is organized as follows: section II describes the subject of "Regulación Automática I". Section III shows the works that are performed by the students by using SLD, taking into account their possibilities of use in Automatic Education. Section IV focuses on the methodology used in the subject. Section V shows the results obtained in the last course. Statistics about the time devoted by the students is summarized according to the survey completed at the end of the course. Finally, section VI summarizes important conclusions.

II. SUBJECT ANALYSIS OF REGULACIÓN AUTOMÁTICA I

The Regulación Automática I contents have been adjusted to cover the important aspects of the subject assuming a realistic balance between workload and dedication of the student [12].

The subject is made up by 144 hours, 78 of which are study hours (Figure 1). They are equivalent to 4.8 credits ECTS.

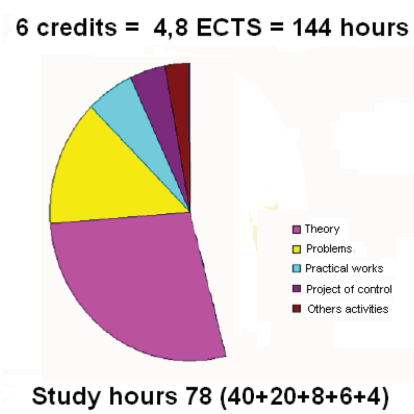

Figure 1. Study hours of students.

The program of the subject is made up by fourteen lessons and eight practical works [12]. This equates to an approximate average of a lesson per week and a practical every fortnight. The studied matters are dedicated to model and analyze discreet systems, as well as to study the feedback systems, with emphasis in the calculation of regulators. One of the chapters is concerned with the methods of system identification using algorithms based on square minimums.

A. Hands-on practices in Regulación Automática I

The subject has three real experiments in the laboratory of automatic.

The first practical work developed by the student consists of the implementation in real time of a system of control with continuous regulator. By means of this practice, the student will be able to analyze the advantages of operation of classic regulators P, PI and PID on a real system. The interface used is Simulink executed in real time with Real Time Target Windows.

In a second practical work, the student makes a model of Simulink in real time testing on a physical system.

The implementation of discreet regulators R (z) is made in a third practical work. In this activity, the student tries to design a discreet regulator by means of some of the techniques studied in class.

The laboratory of practices, where these activities are carried out, is formed by eight positions, each equipped with a computer, a data acquisition card (AD622 of Humusoft), two scale models, a thermal system and DC motors.

B. Practical activities in AulaWeb

The subject has five activities in AulaWeb. In each of them, the student only needs Matlab.

Before making a practical work, the student must complete a self-assessment exercise through AulaWeb.

C. Project of control

The control project is an activity that is made so that the student applies the knowledge acquired in the accomplishment of a control system. The student must choose what technique of modeling and what control tools has to use at every moment.

III. USE OF THE SLD IN THE SUBJECT REGULACIÓN AUTOMÁTICA I

The SLD has the capacity to support any type of practice where measurement and control are electrical signals; at present, the experiences developed, use DC motor and a robot manipulator [13] at UCLV and a thermal system at UPM.

A DC motor and the thermal system are single input and single output process (SISO) that lets to carry out identification, position control, velocity control and temperature control, experiments without loading disturbances.

The robot manipulator is a system with multiple inputs and multiple outputs (MIMO) that exhibits very coupled and stronger non-linear dynamics. It permits to carry out more complex positioning and trajectory tracking control.

The Table I summarize some topics, in Automatic Control Systems Education [14], where the SLD could be effectively used.

TABLE I. TOPICS WHERE THE SLD COULD BE EFFECTIVELY USED

Subjects	Topics
Modeling and simulation	Experimental Identification of SISO Systems. Transient Response Analysis.
Classic Control	Control System Design by Transient-Response. Control System Design by Frequency-Response. Tuning of PID Controller.
Modern Control	Design of Control System in State Space. Design of Regulator-Type by Pole Placement. Design of

	State Observer. Optimal Control Adaptive Control.
Digital Control	Sample Time Selection. Selection and Tuning of digital Controller. Digital Leg Compensation. Digital Lag Compensation.
Robotic	Dynamic Modeling of Manipulators. Trajectory Planning. Independent Joint Control. Computer Torque Feed forward Control. Control with Compensation. Adaptive Control

The SLD is used to make virtual practices and real practices remotely. It is also utilized in the development of the integrated project.

As exposed in [9], the SLD allows the performing of simulated and real practices in two variants: with predefined controller and with controller user defined. In this subject, all the variants for the design of the practices are used.

A. *Real and virtual practices in a remote way*

Real and simulated practices were designed in the SLD for the thermal scale model present in the laboratory (Figure 2). The theoretical transfer function of the thermal system shows in (1).

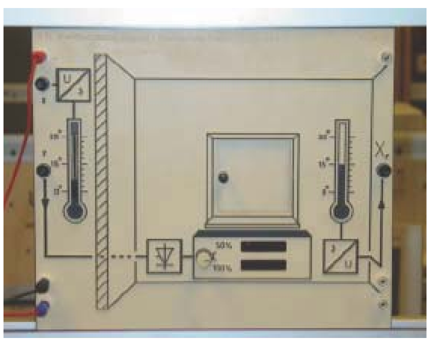

Figure 2. Thermal model

$$G(s) = \frac{0.9}{(1+7s)^3} \qquad (1)$$

Firstly, a practice was made which allowed the adjustment of a regulator PID to obtain the desired results (Figure 3).

This practice agrees with the first practice developed by the student. The reason behind making it remote is that it allows the student to perform new tests and see the effects in the answer of the system.

Figure 3. Web Page of thermal system practices with regulator PID.

The students have numerous possibilities to test the effects of proportional, integral and derivative control actions on the system step transient-response, first by simulation and then in real way.

The simulated and real answer of the thermal system with regulator PID, for Kp = 1, Ki = 0,067 and Kd = 7 as in (Figure 4).

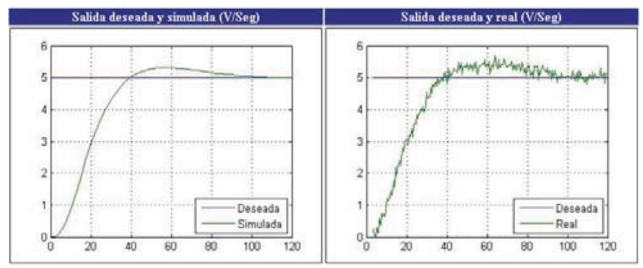

Figure 4. Simulated and real answer of the thermal system with regulator PID

In addition, a practice with controller user defined was designed. With this practice the students prove other algorithms of control and design their own regulators using MATLAB/Simulink.

When a practice with controller user defined is selected, a Web page is shown. This web page permits the downloading of a Simulink file (Figure 5). This file contains the block diagram of the practice. In addition, the user can modify the subsystems Reference and Regulator using software Matlab/Simulink, altering neither the name nor the amount of entrances and exits of the subsystems (Figure 6).

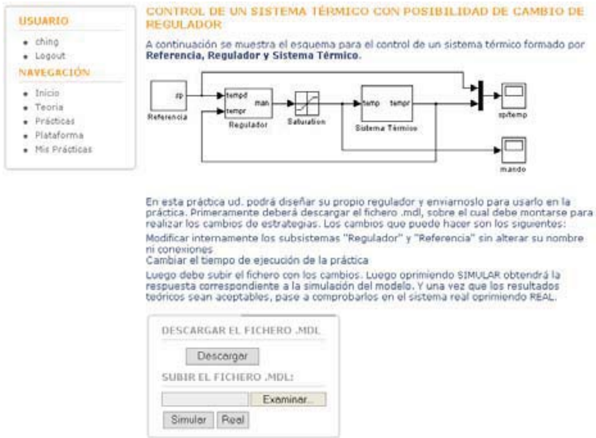

Figure 5. Web Page of thermal system practices with regulator user defined.

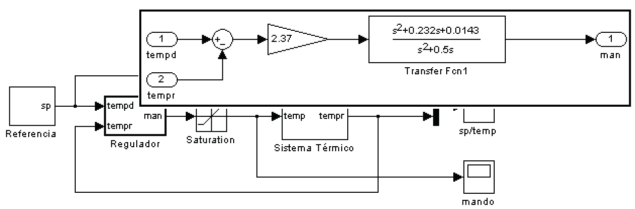

Figure 6. Simulink diagram of thermal system practices with regulator user defined.

B. *Practices developed for the integrated project.*

The integrated project was formed by three parts. In the first the student identified a system that varied depending of its registration number. A practice was designed that showed the answer of the system with white noise in the reference and step in the disturbance (Figure 7). The student identified the different blocks that formed the system, using the methods learned in class.

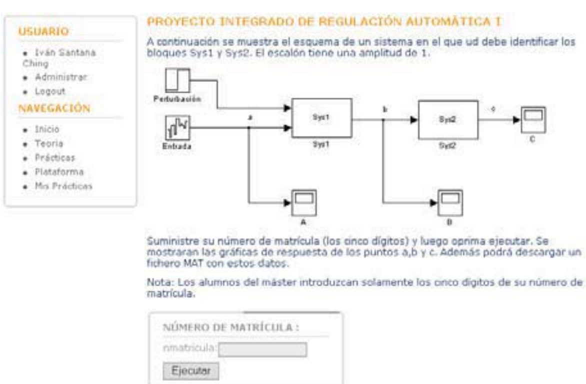

Figure 7. Web Page of integrated project part one.

In the second part, the student designs regulators for the identified system fulfilling some requirements in the answer. The designed practice is of controller user defined. This is the reason why the student designs his regulator and test with the real system comparing the answers.

In the third part, students make designs of compensation such as feedback and cascade compensation. The designed practice is of controller user defined like in the second part.

IV. METHODOLOGY USED IN REGULACIÓN AUTOMÁTICA I SUBJECT

As mentioned previously, this work shows the suitable combination of hands-on experiments, remote practices and activities of self-assessment.

The practical activities with AulaWeb were made several courses ago and allow a continuous assessment of the subject.

The combination of hands-on practices in the laboratory and remote practices was used as methodology, taking advantage of both variants. Hands-on practices have a great formative value for the students. They allow them to know and manipulate the physical equipment with which they work.

Once the student is familiarized with the systems they use, they can work at a distance with them, with the advantages of completion and optimization of the resources. Since the programming and capturing of data require between 10 and 20 minutes, the effective time using the devices is usually reduced. The accomplishments of remote works include time savings for the student and the sharing of resources. This is particularly important when the number of students is large and the equipment is expensive.

Another interesting aspect, that arises when combining hands-on and remote practices, is that the time of use of the equipment is not limited. The students can use them until they consider that they have reached the desired objectives.

In the integrated project, the statement of the different parts took place at AulaWeb, whereas the taking of data, graphs and the test of the regulators at SLD. The practices considered the registration number, thus they guaranteed a different game of data for each student which ensured the project's personalization. The delivery of the information took place through AulaWeb. This allowed the students to continue using the normal method of work and adapt to the SLD without difficulty.

V. RESULTS OBTAINED IN THE SUBJECT

The results obtained in the subject were good. The students were motivated with the use of the SLD for the integrated project. Nevertheless the access to the remote practices was modest, perhaps caused by the lack of information and ignorance of the possibilities that this method presents.

A survey on the subject was carried out. It took into account the following aspects:

- Dedication to the subject.
- Practical works.

Practical activities represent the most important aspect of this work. Items treated from this point of view include:

1. All practical works foster understanding of the subject.
2. The practical works and theoretical classes are balanced.
3. The integrated project contributes to the better understanding of the subject.
4. The time for the accomplishment of the integrated project was sufficient.
5. It was easy to use the Distance Laboratory System (SLD) in the integrated project.

Survey results, in a scale from 1 to 5, behaved as follows (Table II).

TABLE II. RESULTS OF THE SURVEY

Items (1 to 5)	Average	Median	Standard deviation
All practical works foster understanding of the subject.	3.94	4	0.85
The practical works and theoretical classes are balanced.	3.29	4	1.32
The integrated project contributes to the better understanding of the subject.	3.46	4	1.26
The time for the accomplishment of the integrated project was sufficient.	2.23	2	1.17
It was easy to use the Distance Laboratory System (SLD) in the integrated project.	3.19	3	1.22

The results obtained are positive. The students value the practical works which they consider to have a good balance with the theoretical activities. The students positively evaluated the integrated project; however, they considered that the time assigned to carry it out was not sufficient. Conversely, the professors agree that it lacked dedication on the students' part. Finally, the valuation of the SLD in the integrated project may be considered as acceptable, taking into account that it is used for the first time.

It was approved as an educative innovation project aimed at developing and evaluating the impact of new educative tools for learning subjects of Systems Engineering and Automatic.

VI. CONCLUSIONS

The accomplishment of practical works in the subjects of Automatic is a fundamental to achieve quality of teaching. The concepts explained in these subjects have an immediate impact in the implementation of control systems. The type of experiments to make is another important aspect. That is whether the student directly performs them on the physical equipment of the laboratory – as in the traditional way – or experiments accessing equipment remotely or using virtual models that simulate the physical behaviour of the systems.

The adopted option is that the students of the specialty will combine the execution of hands-on and distance practices. This allows them to know the operation of real equipments during the hands-on sessions, as well analyze different schemes from control at distance sessions. This methodology assumes no more than 100 students per classroom.

On the other hand, the students who are not of the specialty will work with virtual laboratories that simulate the behaviour of physical systems. This allows that large groups (classrooms with more than100 students) make several experimental works. In the case of hands-on practices, it would only be possible to make one or two during the course due to the limitation in the number of equipment.

In summary, the use of the SLD brings about a more flexible use of hands-on laboratories and a more rational use of the resources available. In addition, SLD offers the students great possibilities of development and investigation while trying studied algorithms of control in physical plants. The main benefit obtained to date is the reinforcing of the students' learning process when using the combination of hands-on and remote practices. This is derived from the fact that the real hours allow them to familiarize and manipulate the physical equipment directly, whereas remote working hours permit them to test different algorithms and techniques from control without the schedule restrictions.

This methodology increases the practical activities. In addition, students devote more time to the subject during the semester and this effort is rewarded in the final mark.

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A web-based e-learning tool for UML class diagrams

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Abstract— **The paper presents a web-based tool designed to give support to teaching and learning of UML class diagrams. The proposed UML environment is capable to correct automatically UML class diagrams exercises providing feedback to the student immediately. The tool is part of a more general framework, denoted ACME, which provides the main functionalities of an e-learning platform. The tool has been used in a first experimental group of an introductory database course.**

Keywords: UML class diagrams, web-based tools, e-assessment

I. Introduction

Traditionally, a database course uses entity-relationship diagrams (ERD) when teaching conceptual modeling. Describe ERD and how to use them to illustrate conceptual database design is one of the main objectives of an introductory database course [1]. But, despite the popularity of ERD, in last years, different authors have proposed the UML (Unified Modeling Language) class diagram as an alternative to be used instead of ERD notation.

The UML [2] is the standard language for modeling object-oriented applications and is commonly used in the development of software applications. Although, this methodology was developed mainly for software design, a major part of software design involves designing the databases that will be accessed by the software modules. Hence, an important part of the UML is the class diagrams. A class diagram is a type of diagram that describes the static structure of a system by showing the system's classes and the relationships between them. Therefore, it can be considered that class diagrams are similar to ERD in many ways [3]. Moreover, UML provides an advantage with respect to entity-relationship model (ER) since it is widely understood within the computing community, whereas ER is limited primarily to the database community.

In non-academic environments, UML has emerged as an effective modeling tool for database design. On the contrary, it is still rare to see UML class diagram as the primary notation when teaching conceptual data modeling [4]. In academic textbooks the primary modeling techniques are based on ER notation. However, this tendency is changing in recent versions of the books, and chapters presenting UML methodology for conceptual modeling are included [5]. There are also different books focused only on the use of UML for database design [6,7]. These books claim that UML make closer database design with the real business applications.

We agree with [8,9] that this new tendency has to be taken into account in basic database courses, and hence UML class diagram notation has to be taught as well as ERD. Since building UML class diagrams is a complex process, we decided to develop a web-based tool to support its teaching and learning. This tool has being integrated in a more general e-learning framework, denoted ACME-DB, used in database courses of our university. The ACME-DB is used as a support for teaching and learning of the main topics of the course, amongst them, entity-relationship diagrams, relational database schemas, database normalization, SQL and relational algebra. This environment also provides the functionalities required to automatically correct exercises, continuous assessment, etc. The goal of this paper is to present the UML developed tool.

The paper is organized as follows. Section 2 describes related work on UML class diagrams and presents the ACME-DB e-learning environment. Section 3 presents the proposed UML correction tool. Section 4 describes experimental results. Finally, Section 5 presents the conclusions.

II. Related Work

In this section, we review the main concepts of UML class diagrams and their equivalences with ERD. Then, we present previous work on UML modeling tools and finally, the ACME-DB environment where our proposed tool has been integrated.

A. UML class diagram and ERD

There are many similarities between UML class diagrams and ERD [3]. Below we describe them by considering the examples extracted from [5] and illustrated in Fig. 1 and 2, where the same database has been modeled using UML and ERD, respectively.

The entity types in ER are modeled as classes in UML notation. An entity in ER corresponds to an object in UML. In UML class diagrams, a class is displayed as a box that includes three sections: the class name, the attributes and the operations that can be applied to these objects. Operations are not specified in ERD.

Relationship types in ERD are called associations in UML terminology, and relationship instances are called links. A binary association is represented as a line connecting the participating classes and optionally may have a name. A relationship attribute is placed in an association class that is connected to the association's line by a dashed line.

The cardinality in ER model is equivalent to multiplicity in UML terminology and denotes the number of objects that can participate in the relationships. Multiplicities are specified in the form *min..max*, and an asterisk (*) indicates no maximum limit on participation. Possible multiplicities are 0..1, 1..1 (or 1), 1..*, n..m and 0..* (or *).

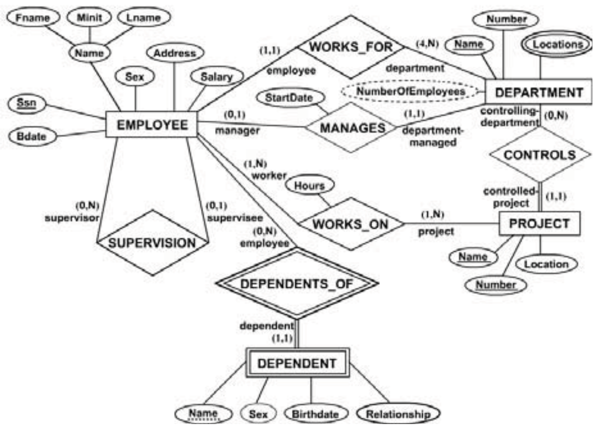

Figure 1. Entity-Relationship diagram of a company database from [5]

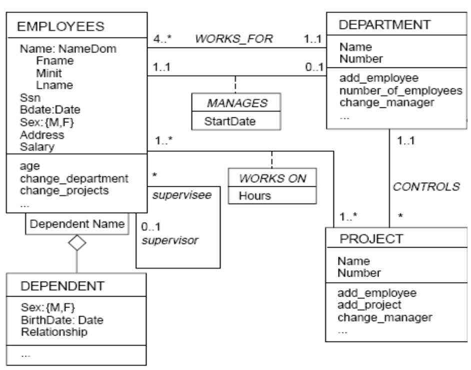

Figure 2. UML class diagram of a company database from [5]

In UML, there are two types of relationships: association and aggregation. An aggregation is meant to represent a relationship between a whole object and its components parts. In UML, it is graphically represented as a hollow diamond shape on the containing class. A composition is a stronger form of aggregation where the part is created and destroyed with the whole. The composition is drawn like the aggregation, but this time the diamond shape is filled. UML also distinguishes between unidirectional associations, which are displayed with an arrow to indicate that only one direction for accessing related objects is needed, and bidirectional that are the default. Weak entities in the ER model can be modeled using the construct called qualified association in UML that can represent both the identifying relationship and the partial key, which is placed in a box attached to the owner class. UML has the ability to specify methods, but when modeling database this feature is not needed as we only deal with data.

The UML is the standard notation for modeling business and software application needs. The main advantage of UML with respect to ER is that it can serve as a unifying framework that facilitates the integration of database design with the rest of a system design.

B. UML modeling tools

Building diagrams is a complex process and different modeling tools have been proposed for creating them. The majority of these tools has been designed for advanced users and only gives support to diagram drawing requirements. In the case of beginners, these tools are not appropriate since more advanced features are required. For instance, it is desired to obtain automatic correction of the diagram and feedback in case of detecting errors. In this section, we will focus on this second group of tools that can be very valuable in the academic context, i.e., tools that not only support drawing needs. Below we describe some of them.

Hoggarth and Lockyer [10] proposed an automated student diagram assessment system that provides a verification mechanism where the student manually compares his solution with the one designed by the teacher. At the end of the comparison process, the system generates a list with the differences with comments that can be used by the student to improve his diagram. H.Ali et al [11] proposed a UML class diagram environment that using notation extraction compares two Rational Rose files. The first file is a description of the UML class diagram proposed by the student and the second one the description of a correct solution defined by the teacher. The system compares these files line by line and generates a list with the differences. Feedback is returned according to this list. Baghaei, Mitrovic and Irwin [12] presented a constraint-based tutoring system for learning UML class diagrams. The system observes students' actions and adapts to their knowledge and learning abilities. The system compares the student solution with the ideal one proposed by the tutor. The comparison process is based on a set of rules. They proposed a single user and also a collaborative version of the tool. Virvou and Tourtoglou [13] proposed an environment for the adaptive support to a software engineering trainer. It considers two users, the trainer, considered an expert, and the student. The system assigns a degree of knowledge to the student and also an expert to monitor his work. N.Le [14] proposed an extension of the ArgoUML tool that allows creating UML class diagrams in a free-form way, i.e., with any restriction with respect to the name of the classes or the attributes. The system provides a set of guidelines to the student to create the diagram.

Despite the capabilities of these tools, in the academic context, it is desired that the e-learning tools provide not only the functionalities for which have been designed but also other functionalities related with academic issues such as continuous assessment, tracking student work, etc. Another limiting factor of these tools is that all of them requires to be installed and the majority requires an additional software for drawing the diagrams [10,11,14]. On the other hand, the tools are independent in the sense that they can not be integrated in a more general framework for giving support to different topics of database courses.

C. The ACME environment

ACME is a web-based environment developed in our university to give support at teaching and learning of different subjects. Originally, it was designed for teaching mathematics in engineering and technical degrees. ACME has a common repository of problems. The teacher can select problems from it and the system automatically generates workbooks. The student enters solutions and the system corrects them returning feedback. All the work is stored in a database and the teacher can extract information for continuous assessment. For a detailed description of the platform please see [15].

The good academic results obtained when applying ACME, encourages us to extend the platform in order to support other subjects. Currently, amongst others, it supports mathematical [15], computer programming [16], database problems, etc.

The set of modules of the platform related with database topics is denoted ACME-DB. We started to develop this environment in 2003 with the development of the relational database schemas module [17]. Since then, normalization [18], entity-relationship diagrams [19], SQL and relational algebra [20] correctors have been developed and integrated in the environment.

Compared with other e-learning platforms, ACME-DB presents, amongst others, the following advantages: (i) It integrates in a single environment, different tools for different database topics; (ii) supports automatic correction of exercises, providing feed-back and (iii) supports automatic student assessment.

Taking into account the limitations of current UML class diagrams tools and the advantages of our environment, we decided to develop the modules required to support UML class diagram correction. Such functionality will be a very valuable tool for teaching and learning conceptual database design in database courses.

III. THE UML CLASS DIAGRAM TOOL

In this section, we present the proposed tool for teaching UML class diagrams. First, we introduce the main design decisions that have been taken into account to develop the tool. Then, we describe the tool from a technical perspective, giving a detailed description of the main modules that compose it.

A. Design decisions

The proposed tool has to be capable of automatically correct UML class diagram exercises in order to reinforce teaching and learning of this topic. To design this tool, we consider that our system has to be able to assign UML class diagram exercises and also the tools required for the students entering the solution, i.e., a graphical interface that allows drawing UML class diagrams.

A second main requirement is the capability to support online correction. The system has to be able to automatically correct the exercises solved by the students. That is, when students enter a solution to a UML problem, it is desired that the system returns immediate feedback with detailed information about errors.

The system has to allow students to enter more than one solution until the correct one is obtained or a deadline is reached. The system has to record all student work, i.e. all attempts entered until the correct one is obtained. Such information will be very valuable for the teacher to carry out a tracking the student progress. The information recorded in the system can be used for continuous assessment purposes. In addition usability requirements are also desired. For instance, the tool has to be easily accessible for teachers and students, no special installation has to be required, only a web browser. The system has to provide a communication channel that enhances student-teacher contact, whether students ask about doubts or teachers give hints about how to solve diagrams.

The ACME environment provides some of the desired requirements, such as, easy access, record of student work, continuous assessment and the student-teacher communication channel. Therefore, to reach our objective we have to focus on the functionalities not provided by the environment and required to support the correction of UML class diagram exercises.

At broad level, we can reduce our problem as it is illustrated in Fig. 3. Our system has to propose exercises, the student will enter solutions, the system will provide feedback according to the correctness of the solution, and this process will be repeated until a certain deadline or the correct solution is obtained. Hence, we have to design two main modules: the class diagram student interface and the class diagram correction module. Both are described in detail the next sections.

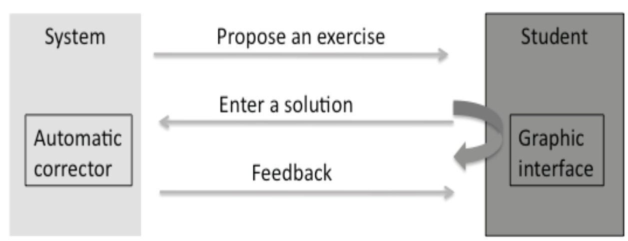

Figure 3. Main functionalities to be considered for the design of the UML class diagram correction tool.

B. The problem structure

Previous to the definition of the different modules that will compose our tool, we have to determine the structure of an UML class diagram problem. This structure is crucial for defining the correction strategy that has to be applied.

We define the problem structure following the guidelines used for the definition of the database problems that are also supported by ACME-DB. It is important to take into account that a UML class diagram problem can have more than one correct solution. The proposed structure is illustrated in Fig. 4. There is a first part with a description of the problem that has to be solved. It consists of a set of requirements for a real life application. A constraint of our approach is that attributes have to appear in the problem descriptor with a specific name and in brackets. Although, the identification of attributes is an important skill to be acquired, for students of introductory database courses we consider more important the capability to properly group attributes in the correct class or attach to the corresponding relationships.

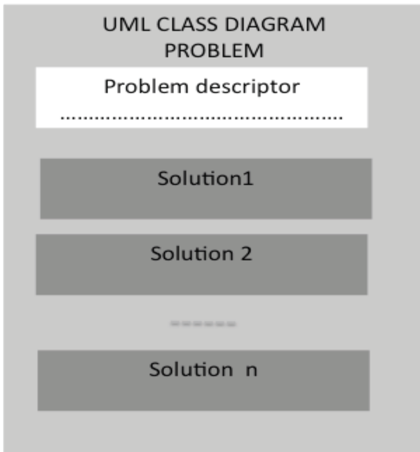

Figure 4. Main parts of a UML class diagram problem.

For each problem we also store a set of possible correct solutions. In Fig. 5, we illustrate the information codified for each solution. We have to specify all the classes and the relationships that define it. We assign one name to each one of the classes and also the list of all its attributes. In the case of association classes, we have to enter also the name of the association with which is related. For the relationships, we have to specify its name, the related classes, its multiplicity and the direction (unidirectional or bidirectional). We also have to indicate if it is an association, aggregation, composition or a generalization. In the case of qualified associations, we have to indicate the qualified class and the qualifier attribute.

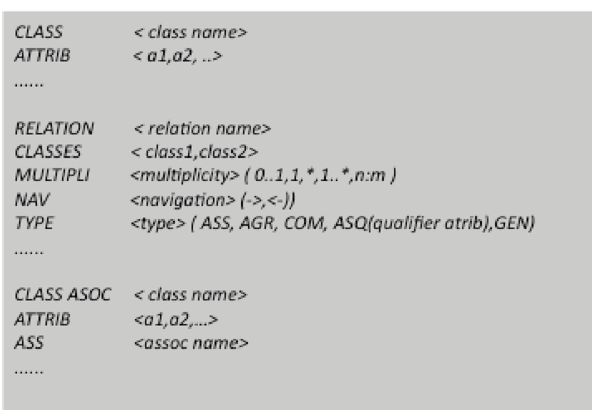

Figure 5. Parameters recorded for each correct solution

The teacher enters the problems and the solutions into the system using a specific editor integrated in the tool that makes easier this task. Each problem is recorded in an independent file, and once it has been created the system verifies that all the parameters have been entered correctly. If the system detects that the entered file does not fit the expected structure, it generates a message indicating where is the error. Problems are stored in a common repository and once saved they are available for being assigned to the students' workbooks. For creating the workbooks the teacher selects exercises from the repository and then the generation module assigns it to the students. Once the student has assigned a workbook, he can select exercises and solve them using the module presented in the next section.

C. *Class diagram interface*

Before presenting the UML class diagram student interface, just to put in context, we briefly describe how the information is showed to the student. Students enter into the ACME environment by using their password. Then, the system presents a list of topics and one of them corresponds to UML class diagram exercises. The student selects this and then accesses to the list of class diagram exercises that have been assigned to his workbook. When he selects one of these exercises it appears an interface with all the information and the tools required to solve it.

In Fig. 6 we illustrate the student interface. Its main parts are: (i) At the top, the problem descriptor area that is the space where the system displays the problem descriptor. (ii) On the left, there is a button bar with the drawing tools that contains a set of buttons where all the elements required for creating a diagram are represented. (iii) In the middle, the working area where the student design the UML class diagram. In this example we show the UML class diagram designed for a database problem from [5]. Since the dimension of the class diagram can be larger than the working area, there is a zoom button to select the part of the diagram it has to be displayed in it. (iii) At the bottom, there is an area with different tabs, each one related with a diagram element. This space is designed for entering the information and the main parameters related to it. For example, when defining a class we enter the attributes, for an association the multiplicity, the type of association, etc. In this example, the association between the two highlighted classes has been selected and hence the corresponding tab allows entering the type of association, related classes, etc.

The student enters the solution and then presses the correct button. In this moment, the correction process (described in next section) starts and when it finishes it returns feedback to the student. Feedback messages appear in an independent window jointly with the sent solution. If the solution is not correct, the returned message gives some advice of how to solve it (see Table I).

D. *Correction module*

The correction strategy is based on a comparison process that proceeds as follow. The solution entered by the student is compared with the possible correct solutions of the problem stored in the repository of the system. If any one of the correct solutions coincides with the one of the student, the solution is considered incorrect. In this case the feedback module selects the solution of the repository more similar to the one proposed

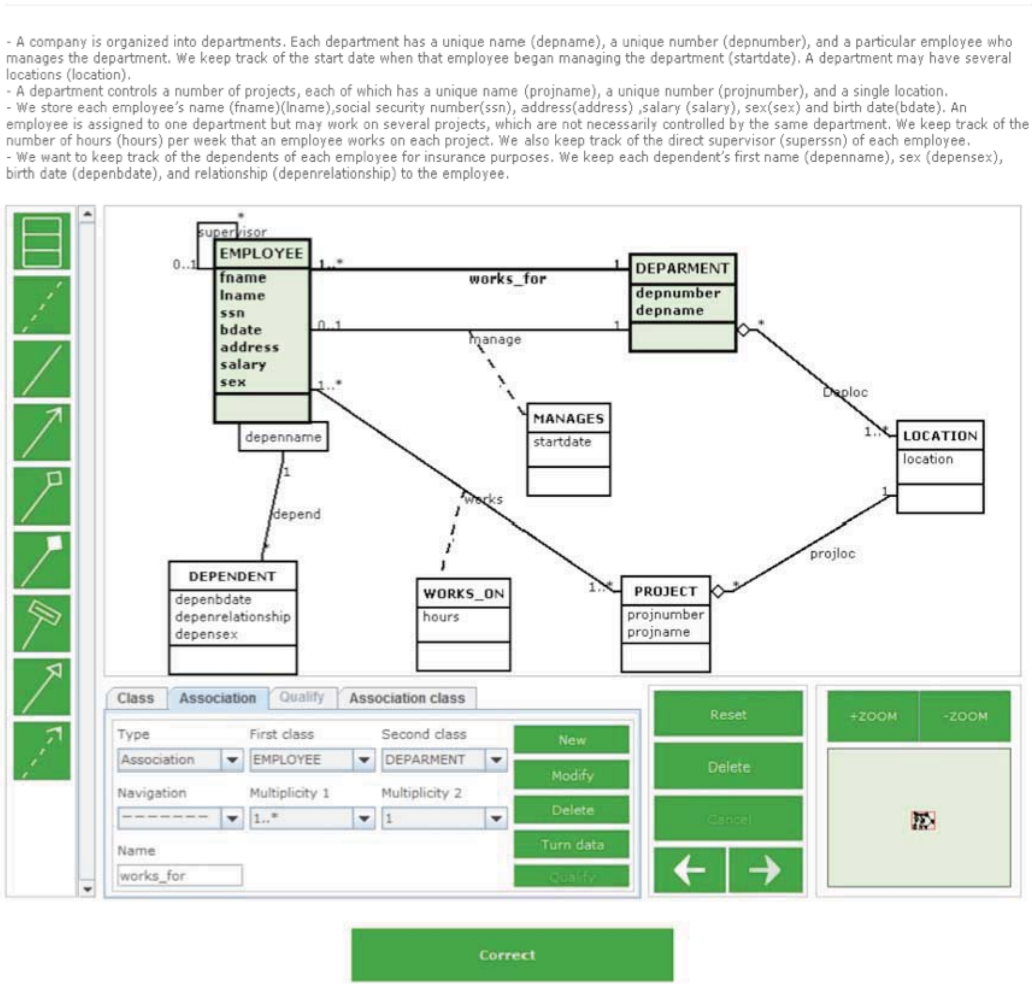

Figure 6. Student interface designed for entering a UML class diagram.

by the student and sends a feedback message to the student. The content of the message aims at driving him to the selected correct solution. The student can enter a new solution and repeat the process until the correct solution is obtained or a deadline has been reached.

The key of the correction process strategy is on the name of the attributes. Note that the only restriction it has been imposed to design the solution is that only attributes marked in brackets in the problem descriptor can be used. There is not any restriction on the names of the class nor the relationships. Classes are corrected by considering the set of attributes attached to it. Relationships are evaluated in terms of the classes they relate, its multiplicity and its type (associations, aggregations, compositions and generalization).

The differences between the correct solution and the student solution determine the message it has to be sent. We have classified the different types of errors that can be found and we have assigned a message to each one of them. The feedback module maintains this set of possible messages and according to the type of error detected by the correction module it automatically selects the message to be sent. In Table I, we report some the message errors.

TABLE I. ERROR MESSAGES GENERATED WHEN AN INCORRECT SOLUTION IS PROPOSED.

TYPE OF ERROR	RETURNED MESSAGE
Number of classes is incorrect	More/less classes are required
Number of associations is incorrect	More/less associations are required
Incorrect class	Class named … is not correct
Association type not correct	Association named … is not correct
Multiplicity error	Multiplicity of association named … is not correct
…	…

E. Integration in the ACME-DB

All presented modules have been integrated in the ACME-DB platform. The modularity of the platform allows such integration to be done easily.

The main advantage of this integration is that ACME-DB becomes a framework capable to give support to main topics of a database course. The student can use it to solve entity-relationship diagrams, relational database schemas and normalization, SQL and relational algebra queries. With the integration of the new tool, now it can also solve UML class diagrams. As far as we know, this is the unique environment that integrates all these features in a single framework.

IV. EXPERIMENTAL RESULTS

To evaluate the proposed tool we consider two groups of students of an introductory database course. The 48 students of the course were divided into two groups of 24 students. In the first one, we used the proposed tool and in the second one any tool was used. In both groups to teach UML we spent the same number of hours. The teacher introduced main UML concepts and then the same exercises were proposed to the students to acquire practice. These exercises require for being solved UML class diagrams with a number of classes that range from four to eight and from six to twelve associations.

In the first group (group A), the teacher introduced some example exercises through the proposed UML tool. Then, a personalized workbook with four different UML exercises was assigned to each student. In the second group (group B), the teacher presented the same examples of group A, but without using the tool. The students solved the exercises by hand. The teacher encouraged students to solve all the exercises and in case of questions, to go to his office.

For each group we collected the number of student and the number of exercise that they solve correctly. The obtained results are reported in Table II. Note that the best results are obtained using the tool.

TABLE II. NUMBER OF STUDENTS AND NUMBER OF PROBLEMS CORRECTLY SOLVED

Number of problems	4	3	2	1	0
Group A	16	4	2	1	1
Group B	10	2	4	4	4

We also evaluate the advantages of the tool from the teacher's point of view. The tool provides information of the type of student's errors. For instance, we detected that the 34,2% of errors are multiplicity errors, 31,3% are association type errors, 17,5% are definition class errors and 17,0% other errors. We also detect that to solve a problem correctly the student requires in average 3,2 attempts.

At the end of UML sessions, students of both groups have to pass an exam. The exam consists in one exercise similar to the exercises assigned to the students. The exam was the same for both groups. In Table III, we illustrate the obtained results, where capitals from A to D represent from excellent to failing the exam, respectively. Although, these results are experimental and need further evaluation with more students, we detect that the students that used the tool obtained better results than the other ones.

TABLE III. EXAM RESULTS

Mark	A	B	C	D
Group A	12	6	3	3
Group B	10	4	6	4

From the teacher's first impressions, we can remark that the environment is easy to use. It does not require any installation, only a web browser. More importantly, it provides gains with respect to the classical teaching methodology in the sense that it offers a system for the continuous assessment of the student's progress, makes personalized attention to the student easier and assesses the degree of participation of the students. The students' impressions have also been positive especially the fact that to access the system they only need an internet connection. During the different sessions students were asked to comment on the problems they faced while using the system. The responses were very positive. The students feel motivated to solve the proposed problems. The possibility to correct a problem in real time encourages them to work until a correct solution is found.

V. CONCLUSIONS

We have presented a UML class diagram tool that provides support at teaching and learning of this topic. This tool has been integrated in the ACME-DB, an e-learning framework for database topics. The tool has been used in a first experimental group with very satisfactory results.

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Session 05D Area 1: Computer and Web based Software - Programming

Evolutionary algorithms for subgroup discovery applied to e-learning data

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Abstract—**This work presents the application of subgroup discovery techniques to e-learning data from learning management systems (LMS) of andalusian universities. The objective is to extract rules describing relationships between the use of the different activities and modules available in the e-learning platform and the final mark obtained by the students. For this purpose, the results of different classical and evolutionary subgroup discovery algorithms are compared, showing the adequacy of the evolutionary algorithms to solve this problem. Some of the rules obtained are analyzed with the aim of extract knowledge allowing the teachers to take actions to improve the performance of their students.**

Subgroup discovery; educational data mining; e-learning systems; evolutionary algorithms; fuzzy rules

I. INTRODUCTION

For almost as long as LMSs exist, researchers have been interested in study how the usage logs of these systems can be used to improve the learning process. The more used approach to exploit this data uses automated evaluation of system logs and databases [1] using data mining techniques to provide additional information for teaching staff about the quality of the student experience. In this sense, data mining techniques can be applied to analyze student's usage data in order to identify useful patterns and to evaluate web activity to get more objective feedback for instruction and more knowledge about how the students learn on the LMS [2].

Educational data mining is an emerging interdisciplinary research area that deals with the development of methods to explore data from an educational context [2]. It is concerned with the development of mining methods to explore the unique types of data in educational settings and, using these methods, to better understand students and learning settings. A data mining algorithm can discover knowledge using different representation models and techniques from two different perspectives: predictive induction, whose objective is the discovery of knowledge for classification or prediction [3]; or descriptive induction, whose main objective is the extraction of interesting knowledge from data. In this area, attention can be drawn to the discovery of association rules following an unsupervised learning model [4], subgroup discovery [5] and other approaches to non-classificatory induction.

Association rule mining [4] is one of the better-studied descriptive data mining methods whose objective is to discover descriptive rules about relations between attributes of a set of data. It has been applied to LMS in order to reveal which contents students tend to access together, or which combination of tools they use [5].

The extraction of association rules has been successfully applied in e-learning systems to discover relationships or associations between the different visited web pages, activities performed, marks obtained, etc. A pioneering work in applying web mining techniques to e-learning systems is [6] which proposes the use of agents [7] to recommend online learning activities or shortcuts in a web course based on access records of students, thereby enhancing the online learning process. Another work that uses association rule mining techniques and collaborative filtering is [8] with the aim of discover helpful navigation patterns and propose a navigation model. The use of methods such as linear regression in combination with association rules to obtain learning transferring patterns of students from the log files in intelligent tutoring systems is proposed in [9]. In [10] is described the use of fuzzy association rules to discover relationships between patterns of student behavior, including access time, number of pages read, questions answered, or read and sent messages. Evolutionary algorithms are used in [11] as a technique for discovering useful information for the authors of such courses, in order to make improvements of the contents, the structure or the adaptation of the courses. Another work using evolutionary algorithms is [12], where an association analysis is performed to predict student performance. Association rules can be adapted to subgroup discovery, a new and very interesting task in educational environments. In fact, this paper proposes the application of data mining techniques for subgroup discovering over educational data.

Subgroup discovery (SD) is a descriptive inductive learning area in which, given a set of data and a property of interest to the user, an attempt is made to locate subgroups which are statistically "most interesting" for the user [13]. A subgroup is interesting if it has an unusual statistical distribution with respect to the property of interest. The objective is to discover interesting properties of subgroups by obtaining simple rules, which are highly significant and with high support.

A rule describing a subgroup has the form:

Condition $\rightarrow$ *Class_label*

where the property of interest for subgroup discovery is the value of the variable (*Class_label*) which appears in the consequent of the rule, and the antecedent of the rule (*Condition*) is a conjunction of features (attribute-value pairs) selected between the features describing the instances of the data set.

Genetic Algorithms (GAs) are beginning to be used to solve SD problems [14], [15] because they offer a set of advantages for knowledge extraction and specifically for rule induction processes. A fuzzy approach in a SD algorithm, which considers descriptive fuzzy rules, allows us to obtain knowledge in a similar way to human reasoning, and so the obtaining of more interpretable and actionable solutions in the field of SD, and in general in the analysis of data in order to establish relationships and identify patterns.

In this work we apply the evolutionary subgroup discovery algorithms SDIGA [14] and MESDIF [16] to obtain fuzzy rules which describe relationships between the student's usage of the different resources provided by the e-learning systems and the final marks obtained. The objective is to characterize subgroups of students whose final marks are significantly different from those of all students, and use this knowledge to improve the learning process. The results obtained by these algorithms are compared with the ones obtained by classical subgroup discovery algorithms, showing the suitability of the evolutionary approach to this problem.

The work is arranged in the following way: Section 2 introduces the subgroup discovery and describes the evolutionary rule induction algorithms used, SDIGA and MESDIF, and the classical subgroup discovery algorithms Apriori-SD and CN2-SD. Section 3 describes the e-learning case study using the Moodle e-learning system implanted in the University of Cordoba, the experimentation carried out, the analysis of the results and of some of the rules obtained. Finally, the conclusions and further research are outlined.

II. Subgroup Discovery: Classical Approaches and Evolutionary Algorithms

In the literature, several different proposals for the extraction of rules in the area of subgroup discovery can be found. Two of the most used classical algorithms for subgroup discovery are adaptations of the well-known algorithms Apriori (used for the extraction of association rules) and CN2 (used for the extraction of rule bases for classification), which are named Apriori-SD and CN2-SD respectively.

There are also evolutionary proposals for the SD task. SDIGA [14] is an evolutionary algorithm for the induction of fuzzy rules which uses linguistic rules as description language for the specification of the subgroups, and adaptations of the measures used in the association rule induction algorithms as quality measures for the subgroup discovery task. MESDIF [16] is a multiobjective evolutionary algorithm using the same quality measures as SDIGA.

A. *Classical subgroup discovery algorithms*

The most widely used state-of-art SD algorithms are described below:

- Apriori-SD [17] uses the weighted relative accuracy as quality measure for the induced rules, using support and significance of each individual rule for the evaluation. It is an adaptation for subgroup discovery of the classification rule learning algorithm Apriori-C [18], based in the original Apriori association rule learning algorithm [4].
- CN2-SD [19] is a modified version of the CN2 classification rule algorithm [20] which induces subgroups in the form of rules using as quality measure the relation between true positives and false positives. As Apriori-SD, it uses a modified weighted relative accuracy measure for the selection of the rules.

B. *Evolutionary rule induction*

In any data mining process there are different tasks or problems which can be approached and solved as optimization and search problems. GAs are general purpose search algorithms which use principles inspired by natural genetics to evolve solutions to problems [21].

GAs have several advantages as a rule induction method: they tend to cope well with attribute interaction (because they usually evaluate a rule as a whole), have ability to scour a search space thoroughly, or allow to find complex interactions due to the implicit backtracking in its search of the rule space. This makes GAs particularly suited for the SD task.

The genetic representation of solutions is the most determinant aspect of any rule induction GA. In this sense, the proposals in the specialized literature follow two approaches in order to encode rules within a population of individuals [22]:

- The *"Chromosome = Rule"* approach, in which each individual codifies a single rule.
- The *"Chromosome = Set of rules"*, also called the Pittsburgh approach, in which each individual represents a set of rules.

Within the "*Chromosome = Rule*" approach, three generic proposals can be found: the *Michigan* approach, the *Iterative Rule Learning* (IRL) approach and the *cooperative-competitive* approach. A complete description of the different proposals for the evolutionary induction of rules can be found in [22].

In processes aimed to the extraction of rules for the subgroup discovery task, the "*Chromosome = Rule*" approach is more suited because the objective is to find a reduced set of rules in which the quality of each rule is evaluated independently from the rest, and it is not necessary to evaluate the set of rules jointly.

Among the different proposals of GAs for the description of subgroups, below are described two focused in this approach.

C. *Evolutionary rule induction algorithm SDIGA*

SDIGA (Subgroup Discovery Iterative Genetic Algorithm) is an evolutionary model for the extraction of fuzzy rules for the subgroup discovery task. This algorithm is described in [14], including here a brief summary of its key features.

In the subgroup discovery task we must distinguish between a set of descriptive variables and a single target variable which describes the subgroups. As the objective is to obtain a set of rules describing subgroups for all the values of the target variable, the GA of this proposal discovers fuzzy rules with the consequent prefixed to one of the possible values of the target variable. In this way, each run of SDIGA obtains a set of rules corresponding to the value specified for the target variable, and the algorithm must be run for each one of the possible values of the target variable.

In this proposal, each candidate solution is coded according to the *"Chromosome = Rule"* approach representing only the antecedent of the rule in the chromosome (since all the individuals of the population are associated with the same value of the target variable). The antecedent of a rule is composed of a conjunction of variable-value pairs. The information related to each rule is stored in a fixed length chromosome using an integer representation model (in which the i-th position indicates the value of the i-th variable).

The core of SDIGA is a GA which uses a post-processing step based on a local search (a hill-climbing procedure). The hybrid GA extracts one simple and interpretable fuzzy rule. The post-processing step is applied in order to increase the generality of the extracted rule. The optimized rule will substitute the original one only if it overcomes minimum confidence.

The GA uses a modified steady-state reproduction model, with the aim of increasing the diversity of the population, in which the original population is modified through the substitution of the worst individuals by individuals resulting from crossover and mutation. A two-point crossover operator is applied to the two best individuals of the population, obtaining two new individuals, who will substitute the two worst individuals in the population. Mutation is carried out by means of a biased random mutation operator applied to the gene selected according to the mutation probability. The mutation can eliminate the variable selected or assign a random value.

This hybrid GA is included in an iterative process for the extraction of a set of rules describing different parts (not necessarily apart) of the search space. A set of solutions generated in successive runs of the GA is obtained, corresponding with one value of the target variable. This is accomplished by checking the instances covered by the obtained rule, preventing a new rule to cover exactly the same examples. Thus different fuzzy rules are obtained, although they may be overlapping.

The model uses fuzzy rules, which provide better interpretability for the rules extracted by means of the use of a knowledge representation near to the expert, also allowing the use of numerical variables without a prior discretization. The fuzzy sets for the linguistic labels defined by the corresponding membership functions can be specified by the user or defined by a uniform partition if there is no available expert knowledge (using uniform partitions with triangular membership functions).

The evaluation function of the GA combines, according to the following expression, three factors: confidence (*Conf*), support (*Supp*) and unusualness (*Unus*):

$$fitness(c) = \frac{\omega_1 \cdot Conf(c) + \omega_2 \cdot Supp(c) + \omega_3 \cdot Unus(c)}{\omega_1 + \omega_2 + \omega_3} \quad . 1$$

in which w_i are the weights assigned to each measure, allowing to establish the importance of each one of the measures.

These measures are computed in the following way:

- *Confidence*. Determines the relative frequency of examples satisfying the complete rule among those satisfying only the antecedent. In this paper we use an adaptation of Quinlan's accuracy expression [23] in order to generate fuzzy rules [24]: the sum of the degree of membership of the examples of this class to the zone determined by the antecedent, divided the sum of the degree of membership of all the examples that verifies the antecedent part of this rule (irrespective of their class) to the same zone.
- *Support*. It is a measure of the degree of coverage than the rule offers to the examples of the class. This measure aims to promote the extraction of different rules in successive runs of the hybrid GA. This, for the computing of the support we only consider the examples not covered by rules obtained in previous runs of the GA. This way, support is defined as the quotient between the number of new examples covered by the rule and the number of not covered examples of the data set.
- *Unusualness*. It is also known as the weighted relative accuracy. It measures the balance between the coverage of the rule and its accuracy gain and is normally used as a measure of the interest of the rule.

The overall objective of the evaluation function is to guide the search towards rules that maximize the accuracy and the interest of the rule, also minimizing the number of negative and not covered examples.

D. *Multiobjective evolutionary algorithn MESDIF*

This multiobjective evolutionary proposal [16] extracts rules using the same representation as the SDIGA algorithm, and its objective is the extraction of a variable number of different rules for each value of the target variable. The algorithm allows the extraction of fuzzy and/or crisp rules, for problems with continuous and/or categorical variables.

The multiobjective GA follows the SPEA2 approach [25], and so applies the concepts of elitism in the rule selection (using a secondary population) and the search of optimal solutions in the Pareto front (the individuals of the population are ordered considering if each one of them is or not dominated by others using the concept of Pareto optimal). Any multiobjective GA must be designed aimed to reach two objectives: obtaining of good approximations to the Pareto front and maintaining the diversity of the solutions in order to adequately sample the space of the solutions and not to converge to a single solution or to a bounded section of the Pareto front. To preserve diversity at a phenotypic level the algorithm uses a niche technique that considers how close the values of the objectives are. Table I shows the operation scheme of the proposed model.

In this subgroup discovery process the objective is the extraction highly descriptive capacity, comprehensible and interesting rules. So, three objectives have been defined in this multiobjective proposal: support, confidence and unusualness. Confidence and unusualness are defined in the same way as in SDIGA, but a different definition of support is used because the algorithm obtains sets of different rules without using an iterative model. In his case, support is defined as the quotient between the number of examples of the class described by the rule and the total number of examples of the class.

This algorithm uses an elite population with a fixed size, and so it is necessary to define functions for truncation and filling. The truncation function allows the elimination of non-dominated solutions from the elite population if it exceeds the defined size. For this purpose it is used a niche schema defined around the density measured by the distance to its k-th nearest neighbour, in which, in an iterative process, in each iteration it is eliminated from the elite population the individual that is nearest of others respect of the values of the objectives. The fill function allows adding dominated individuals from the population and the elite population until the exact size of the set is reached (ordering the individuals according to their fitness values).

The algorithm uses the following reproduction model:

- Join the original population with the elite population obtaining then the non-dominated individuals of the joining of these populations.
- Apply a binary tournament selection on the non-dominated individuals.
- Apply recombination to the resulting population by a two point cross operator and a biased uniform mutation operator in which half the mutations carried out have the effect of eliminating the corresponding variable, in order to increase the generality of the rules.

TABLE I. OPERATION SCHEME OF THE PROPOSED EVOLUTIONARY ALGORITHM

Initialization: Generate an initial population P_0 and create an empty elite population $P'_0 = \emptyset$.
Repetir
Fitness assignment: Compute fitness values for the join of the individuals in population P_t and in elite population P'_t.
Environmental selection: Copy al non-dominated individuals in population P_t and in elite population P'_t in the elite population P'_{t+1}. If the size of P'_{t+1} is bigger than the number of individuals to store, reduce P'_{t+1} by a truncation operator; otherwise, if the size of P'_{t+1} is lower than the number of individuals, fill with dominated individuals of P_t and P'_t.
Mating selection: Perform binary tournament selection with replacement on elite population P'_{t+1} applying later crossover and mutation operator to fill the matting pool. The result is the population P_{t+1}.
While stip criteria is not verified.
Return the non-dominated individuals in elite population P'_{t+1}.

III. E-LEARNING CASE STUDY: USAGE DATA OF THE MOODLE E-LEARNING SYSTEM OF THE UNIVERSITY OF CORDOBA

In this section we examine the e-learning case study. First, we describe the problem and then the experimental results obtained in the execution of the different subgroup discovery algorithms are shown. Finally, an analysis from the point of view of the teacher of several of the rules obtained is performed with the aim of improving the e-learning courses.

As we have mentioned previously, we have used student's usage data of the Moodle system [26], one of the most used web-based e-learning systems. Moodle is an alternative to proprietary commercial online learning solutions, is distributed free under open source licensing and has been installed at universities and institutions all over the world.

The aim of the use of subgroup discovery in this problem is to analyze the possible relation between the usage of complementary activities of a course and the final marks obtained by the students. The final mark is used as the variable to characterize, using the different marks to divide the data into classes and codifying them as values of the consequent of the rules.

We have run different subgroup discovery algorithms in order to compare the results and show what type of algorithm discovers more useful knowledge for the course teacher. The objective is to present the results to the teacher in the form of rules in order to allow the use of this knowledge in the decision making concerning the complementary activities of the course. For example, the teacher can decide to promote the use of some type of activities to obtain a high mark, or on the contrary eliminate some activities because they are associated with low marks.

The Moodle system contains a great deal of detailed information on course content, users, usage, etc., stored in a relational data base keeping detailed logs of all the activities performed by the students. We can use these logs in order to determine which students have been active in the course, what they did, when, or if everyone has done a certain task or spent a required amount of time online within certain activities [27].

We have available information corresponding to 192 different courses of the University of Cordoba. Among all these courses, we have chosen 5 courses, corresponding to the subjects with the highest usage of the activities and resources, involving a total of 293 students. Although our approach can be applied to just one course we have selected courses with high student participation in order to generalize the results. However, there is no a minimum amount of students to obtain any rule.

We have applied a pre-processing step to the information, obtaining a summary table with the most important information related to our objective. Table II shows this summary table, including the activities completed and the mark obtained by each student in an e-learning course. We have discretized the marks into classes (fail, pass, good and excellent) in order to codify them as the values of the rule consequent. The information obtained has been exported to a text file using the structure of the KEEL platform files [28] because the subgroup discovery algorithms used are implemented for the KEEL data mining platform.

TABLE II. ATTRIBUTES USED FOR EACH STUDENT

Name	Description
course	Identification of the course
n_assigment	Number of assignments completed
n_assigment_a	Number of assignments passed
n_assigment_s	Number of assignments failed
n_quiz	Number of quizzes completed
n_quiz_a	Number of quizzes passed
n_quiz_s	Number of quizzes failed
n_messages	Number of messages sent to the chat
n_messages_ap	Number of messages sent to the teacher
n_posts	Number of messages sent to the forum
n_read	Number of forum messages read
mark	Discretized student's mark

A. *Experimental results of the application of subgroup discovery algorithms*

The experiments had been performed using four different algorithms in order to compare their results and determine the most appropriated approach: the classical subgroup discovery algorithms Apriori-SD and CN2-SD and the evolutionary algorithms SDIGA and MESDIF.

We have performed several runs of the different algorithms in order to obtain the average values of the measures used to evaluate the quality of the rules.

For the classic deterministic algorithms Apriori-SD and CN2-SD we have performed a set of runs, varying one of their parameters each time. In the case of Apriori-SD, we have used 4 minimum confidence values (0.6, 0.7, 0.8 and 0.9) varying the minimum support value (0.03, 0.1, 0.2, 0.3, and 0.4). In the case of CN2-SD, we have used the γ parameter (0.9, 0.7, 0.5 and additive) varying the star size (1, 2, 3, 4, 5).

For the evolutionary algorithms, we have performed 5 different runs for each of the values of the target variable (fail, pass, good and excellent) using a population of 100 individuals, a maximum number of evaluations of individuals in each GA run of 10000, a crossover probability of 0.6, a mutation probability of 0.01, and 5 linguistic labels for the continuous variables (very high, high, medium, low, very low).

In addition, the weights used for the fitness function in the SDIGA algorithm are: 3 for accuracy, 1 for coverage and 4 for significance. This set of weights has been chosen according to the results obtained in an experimental study. For the SDGA algorithm, different values of the minimum confidence (0.6, 0.7, 0.8 and 0.9) are used. For the MESDIF algorithm, different elite population sizes are used (3. 4, 5 and 10).

Table III shows the results obtained by the classic algorithms with their different parameter values and the averages of the 5 runs of the evolutionary algorithms with each value of minimum confidence. The table shows the total number of rules obtained, the number of attributes in the antecedents of the rules and the values of their quality measures (support, confidence, unusualness and significance).

In order to analyze de results with respect to the number of rules and the number of variables of the rules, we have to take into account that a key aspect in our problem is the interpretability of the results. In this sense, we are interested in the extraction of a reduced set of rules with a low number of attributes. This will facilitate the understandability of these rules for the teacher.

TABLE III. EXPERIMENTAL RESULTS OF THE ALGORITHMS

Algorithm	*Number of rules*	*Number of attributes*	*Support*	*Confidence*	*Unusualness*	*Significance*
SDIGA MinCnf 0.6	5.4	3.1600	0.7418	0.7709	0.0340	20.0671
SDIGA MinCnf 0.7	4.8	2.8000	0.8096	0.5716	0.0378	23.1872
SDIGA MinCnf 0.8	5.4	3.2583	0.6534	0.6805	0.0319	21.4395
SDIGA MinCnf 0.9	6.2	3.1821	0.3815	0.7769	0.0200	14.4846
MESDIF Elite 3	12.0	3.2000	0.9795	0.4466	0.0173	21.7596
MESDIF Elite 4	16.0	3.4125	0.9890	0.4242	0.0234	24.7158
MESDIF Elite 5	20.0	3.6500	0.9884	0.4517	0.0241	23.6884
MESDIF Elite 10	40.0	3.6950	1.0000	0.4732	0.0284	23.8734
Apriori-SD MinCnf 0.6	9.8	1.0400	0.5924	0.6157	0.0183	27.3901
Apriori-SD MinCnf 0.7	10.4	1.3238	0.5513	0.6301	0.0176	31.4304
Apriori-SD MinCnf 0.8	5.0	0.8294	0.3734	0.3842	0.0205	21.2968
Apriori-SD MinCnf 0.9	4.6	1.1692	0.2089	0.3787	0.0192	21.0734
CN2-SD (γ=0.5)	15.6	5.6406	0.9342	0.7143	0.0264	45.8554
CN2-SD (γ=0.7)	18.4	5.6857	0.9876	0.7177	0.0349	47.0058
CN2-SD (γ=0.9)	25.2	5.7177	0.9890	0.7184	0.0315	47.2862
CN2-SD (add)	31.5	5.7741	1.0000	0.7129	0.0273	54.7134

Thus, in this aspect the results of SDIGA are better than the results of the classical subgroup discovery algorithms.

With respect to the quality measures, it can be seen that:

- For the support measure, MESDIF and CN2-SD obtain the best results, obtaining rules with a high generality, so covering most of the students. MESDIF obtains the same results as CN2-SD but with a lower number of attributes. SDIGA also obtains high values in this measure.
- Related with the confidence or precision of the rule, which indicates the number of students covered by the antecedent of the rule and which correspond to the class associated to the same, the best results are obtained by SDIGA and CN2-SD, which obtain rules with a good level of precision.
- For the unusualness, the best results are obtained by the SDIGA algorithm, but all the algorithms obtain similar values in this quality measure.
- Finally, significance measures the relevance and interest of the rule. CN2-SD is the algorithm that obtains the best results in this measure, and both evolutionary algorithms obtain results very similar to that of Apriori-SD.

The most desirable algorithm with regard to the values of these quality measures would be an algorithm that simultaneously shows the highest values for all the measures. As we have seen there is not a single algorithm which achieves this. Then we have to consider the interpretability of the results for the teachers. In this sense, the evolutionary algorithms offer knowledge with a reduced number of rules and variables. In addition, the use of fuzzy rules in SDIGA and MESDIF contributes to the interpretability of the extracted rules due to the use of a knowledge representation nearest to the expert, also allowing the use of continuous features without a previous discretization.

B. Analysis of the comprehensibility of the rules obtained by evolutionary algorithms

According to the results shown in the previous section, the evolutionary algorithms for subgroup discovery take advantage over the classic algorithms in relation to the comprehensibility of the rules extracted when using them in the decision making of the teacher of a course. This is due to the use of attributes of the form “LABEL = VALUE”, where VALUE are linguistic labels provided by the expert, which allow an easier interpretation for the teacher.

On one hand, rule induction algorithms are normally also considered to produce comprehensible models because they discover a set of IF-THEN classification rules that are a high-level knowledge representation and can be used directly for decision making. Some examples of rules obtained by a rule induction algorithm are:

IF n_assignment < 6 THEN mark = FAIL

IF n_assignment > 10 AND n_quiz_a > 9 THEN mark = GOOD

IF course = 29 AND n_quiz_a = 0 THEN mark = FAIL

IF course = 110 AND n_quiz_a > 7 THEN mark = GOOD

On the other hand, fuzzy rule algorithms obtain IF-THEN rules that use linguistic terms that make them more comprehensible/interpretable by humans. So, this type of rule is very intuitive and easily understood by problem-domain experts like teachers.

Below are shown a few examples of rules discovered by the evolutionary algorithms, analyzing their meaning a applied to the improvement of the courses.

IF course = 110 AND n_assignment = High AND n_posts = High
THEN mark = Good
Support: 0.7045 Confidence: 0.7231

For the course 110, students who have done many activities and have sent many messages to the forum have obtained a high mark. The teacher of this course should continue promoting such follow activities as they have been proven effective in the final mark obtained by the students who carry them out.

IF course = 88 AND n_messages = Very High
THEN mark = Fail
Support: 0.1930 Confidence: 0.9444

For the course 88, students who have sent a lot of messages to the chat have failed. The teacher of this course should eliminate the chat because it has no provided any benefit to the students, but on the contrary it can be seen as a source of distraction.

IF n_read = High AND n_messages_ap = Very low
THEN mark = Fail
Support: 0.1176 Confidence: 0.7500

For any course, if the number of messages read from the forum is high but the number of messages sent to the teacher is low, then the final mark is fail. This rule provides information on a small group of students who tend to fail. The teacher can then pay more attention to these students trying to motivate them in time to pass the course.

Finally, in our educational problem the final objective is to show the instructor interesting information about student marks depending on the usage of Moodle courses. Then, the instructor can use the discovered knowledge for decision making about activities. For example, some of the rules discovered show that the number of quizzes passed in Moodle was the main determinant of the final marks, but there are some others that could help the teacher to decide whether to promote the use of some activities to obtain higher marks, or on the contrary, to decide to eliminate some activities because they are related to low marks. It could also be possible for the teacher to detect new students with learning problems in time to remedy (students predicted as *Fail*).

IV. Conclusions

In this work the application of subgroup discovery techniques to data from a real world problem of knowledge extraction in e-learning systems.

After testing the proposed algorithms by comparing them with other classical subgroup discovery algorithms, it appears that evolutionary algorithms are well suited for solving the proposed problem. They obtain a reduced set of understandable rules (due both to their small size and to use of linguistic labels) that make them more interpretable to the teacher, in addition to obtaining similar values in the other quality measures. Based on the rules obtained, teachers can make decisions about course activities to improve the performance of their students.

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Computation for Science and Engineering

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***Abstract*—Computation for Science and Engineering is an introductory computer science course for students majoring in fields other than computer science. This course, which was previously taught as a traditional introductory course focusing on syntax of C, will be offered with its new curriculum in Spring 2010. The new curriculum defocuses syntax and involves students in analyzing dynamic systems, which are frequently not deeply understood by students attending science and engineering courses. This course aims at attracting more non-computer science majors into computing disciplines and providing students with a deeper understanding of dynamism of real-life situations.**

Keywords-dynamic systems, programming, computing fields

I. Introduction

Motivated by Mark Guzdial's observation that programming is more accessible when examined in the context of interesting and engaging problems [1], we have recently developed at the University of Texas at El Paso (UTEP) a programming course offered to entering college students titled "Introduction to Computational Systems" (ICS) that examines the mathematics underlying familiar physical phenomena such as ballistics and resonance [2].

A typical project in ICS will be a short (4-15 line) program simulating a simple dynamic system whose output is drawn as a raster image. While the plots generated by these programs are essentially equivalent to the display of a graphing calculator, it appears that student definition of the system's evolution as a simple iterated sequence of instructions provides a heightened visceral-level understanding of the mathematics underlying a system's evolution. Furthermore, much like manipulatives used in math courses, the programs are sufficiently simple to be easily analyzed and repaired when a student discovers that their program evolves in an inappropriate manner. The preliminary evaluation of this course indicates that attendees quickly develop competency at basic programming tasks and have favorable attitudes towards learning about the mathematics of dynamic systems using computation in this manner [3].

Driven by the early success of ICS course, we are developing a new curriculum for the introductory computer science class for students not majoring in computer science. Computer Programming for Scientists and Engineers (CPSE) is a course at UTEP intended to teach basic computer programming skills to undergraduate students majoring in STEM disciplines other than computer science. The previous curriculum was a traditional introduction to programming that focused on the syntax and semantics of the C language and did not draw connections to attendees' majors. CPSE attracted too few students to be offered regularly.

We describe a new curriculum for CPSE, now titled "Computation for Science and Engineering" (CompSE), which will be introduced in Spring 2010. CompSE offers a more problem-oriented approach to learning programming concepts and uses the pedagogical approaches of our ICS curriculum to introduce programming as a tool for understanding the dynamism of systems of relevance to attendees' science-technology-engineering-math (STEM) academic majors.

One of the main goals of CompSE is to attract students not majoring in computer science to computational sciences courses and stimulate their interest in continuing study of computation. To achieve these goals, CompSE aims at attaining three main learning objectives.

1. Students will examine and understand the basis of analytical techniques that they have probably seen and memorized in mathematics or science courses but have frequently not been comprehended deeply enough to be able to apply them to real-life problems.
2. Students will learn how computation can be used to analyze problems that are difficult or impossible to understand using only analytical techniques, and
3. Students will realize that real-life problems expose common challenges to simulation such as catastrophic errors due to effects of round-off error or inappropriate simulation interval.

II. Motivation for Computation for Science and Engineering

While programmed computation is a key tool to understanding the evolution of dynamic systems across the sciences, it is unusual for students in traditional science majors to attend a course that teaches programming skills. Furthermore, traditional introductory programming courses rarely expose the relevance of computation to these disciplines. In order to engage a larger number of students from traditional scientific disciplines in computational sciences, CompSE focuses on the development and examination of programs that simulate dynamic phenomena drawn from these disciplines. These simulations typically compute the sum of finite differences that are computed at each simulated time-step and also provide an alternate learning pathway for understanding underlying mathematical concepts.

Through this approach the course exposes the utility of simulation in examining the evolution of realistic systems whose complexity limits the accessibility of analytical evaluation. CompSE thus motivates the use of computation to the study of compelling realistic situations rather than hypothetical or simplified examples frequently found in coursework.

In order to stimulate students' interest to continue study in computational systems, CompSE aims at improving students' understanding of real-life dynamic systems by use of computer simulations. One of our key objectives is to provide a visceral level understanding of the characteristics of stable, periodic, and unstable systems that include feedback effects such as investment, production-consumer markets, predator-prey models, muscle contractions, impact of environmental conditions on living organisms, and the development of cancer.

Families of dynamic systems are examined as threads of inquiry drawn from various disciplines in which layers of complexity are progressively added to increase the realism of the computational model. We begin with a financial modeling thread, and continue with examining threads in other fields including environmental science and molecular biology.

Besides the mastery of basic programming concepts, anticipated learning outcomes of this course also include an understanding of the power and limitations of simulation, visceral understandings that simple systems can have highly dynamic behavior, and interest in continued study of computational systems.

Our planned evaluation for the success of this curriculum will examine both the effectiveness of the course in achieving student learning objectives, and student interest in continuing multi-disciplinary studies that include computation and programming.

III. COMPUTATION FOR SCIENCE AND ENGINEERING

The new curriculum will be offered for the first time in the Spring of 2010. By this curriculum, like ICS, rather than initially focusing on syntax, CompSE will instead immerse students in problem solving and incrementally introduce language features in an as-needed manner. Python is selected as the initial programming language due to its simplicity to convey major programming skills, and C is introduced later in the semester to demonstrate to students the ease of learning a new programming language once they are comfortable using Python.

The new curriculum still examines foundational programming concepts such as input and output, branching and loop statements, and objects. However, the presentation of these concepts is driven by the needs of the projects being examined rather than following a more traditional approach in which programming concepts to be taught are determined first, and the examples to demonstrate these notions are chosen based on the concepts that are to be explained.

Dynamic systems are examined in modules chosen from various disciplines including physics, finance, biology, and environmental science. Each dynamic system is originally presented under simplifying assumptions, which make it easier for students to understand the basic principles of the system at hand. After the initial comprehension of the underlying dynamic system, layers of complexity are progressively added to modeling of the system to increase the realism of the computational model.

Below, we describe several modules of CompSE. Each examines an evolving sequence of challenges that permit students to engage in discovery-learning as they first understand and implement simplistic models, discover their naïve assumptions, and then discover and apply successive refinements that reflect deepening understandings of the problem.

A. Investment Module

We begin with a financial modeling thread that first implements simple interest that might be offered by a bank. It is clear that, using this approach, the amount of money in a bank account is represented by a linear function. However, the students are asked to simulate the balance in consequent years, for a given initial investment and interest rate, without finding the exact equation of the line. Only after experimenting with different initial amounts and interest rates, students become familiar with expected behavior of the investment system in the case of a simple interest rate. Moreover, students are asked to relate the behavior of the system to known mathematical functions, which is expected to deepen their understanding of simple mathematical functions, such as linear functions.

The next layer of complexity is added by considering compound interest, which yields an exponential function. Students are led through similar steps as in the case of a simple interest in order to understand a more realistic investment system and, at the same time, understand the behavior of exponential functions.

Subsequent labs examine the selection of alternative investment instruments such as stocks and real estate. We first consider two criteria for investing in stocks – return and risk, for which we can define a stable (possibly linear) relationship: if the return of a stock increases, the risk of investing in this stock increases as well [4]. However, in reality, when the risk reaches a certain high point, no one will invest money in the stock even if it offers high return, and therefore the established (linear) relationship between return and risk becomes invalid. The course explores how this new phenomenon could be modeled. Naïve models are demonstrated to be inadequate when the resulting system reaches an absurd state. Various approaches to refining the models are examined such as piece-wise corrections, higher-order approximations, or alternate models.

In the first case, boundaries of the regular behavior are established (i.e., until which point the relationship between risk and return is linear), and the branching condition is placed at this point. The already built model is used until the boundary condition is reached, and a new model is built for the remaining part of the problem.

In the second method, the existing model is thrown away and a new model is built to address the new situation. Instead of using a linear relationship between return and risk, possibility of using mathematical functions that tend towards some horizontal asymptote are examined, such as exponential and logarithmic functions.

Furthermore, the course explores models of how a financial system can continue to evolve including the risks of oscillatory behavior, market crash, and various approaches that can lead to stable recovery.

The effect of simulation granularity and utility of mathematics in modeling these systems is also explored. Market crashes could result in losing money, thus the amount of money in investment instruments decreases rapidly in this situation. If appropriate/sufficient/enough attention is not taken during the simulation, this amount might become negative, which is not an adequate representation of the real-life situation. In order to repair the simulation, students need to determine when exactly the value becomes zero. However, it might not always be possible to find the exact value due to granularity of the simulation. Thus, students are forced to accept an approximate value as the solution, therefore facing the round-off error in this particular problem.

The finance module of CompSE is accessible to students with a variety of academic backgrounds. The course assumes that students have only a superficial understanding of investment and familiarity with high-school algebra. As in ICS, each type of dynamism and its effects are incrementally taught and examined through incorporation into students' simulated computational systems.

B. Environmental Science Module

CompSE continues by examining dynamic systems from other disciplines including environmental science and the impact of environment on living organisms.

Through the simulation of a simple agricultural ecosystem, the lab sequence examines the nature of random processes, their effect on dependent stateful dynamic systems, and the Monte-Carlo method. At each time step, the evolved health (state) of the plant population is modeled as a function of current health and current climate conditions. For example, a simplistic model of a healthy plant will transition through several states of diminished health when subjected to drought, and its recovery to a healthy state will similarly require a prolonged period of adequate irrigation.

Lab exercises will examine the nature of randomness in climate models. For example, in an early lab, the simulation of irrigation water availability is naively simulated as an independent random daily event with fixed probability. Students can run multiple Monte-Carlo experiments and determine the relationship between expected availability of irrigation water and probability that the crop will fail.

Subsequent exercises challenge students to develop more realistic climate models and to examine their effect on plant resilience. In addition, projects can model or simulate more complex models of ecosystems such as ones that include reproduction or competition.

C. Molecular Biology Module

In contrast to the familiar finance and environmental science examples described above, it is unusual for students not studying biology to be familiar with the processes of molecular biology. This section offers most students the opportunity to understand unfamiliar biological processes and approaches to simulating uncertainties and constraints.

One of the problems that we model in CompSE is development of cancer. For example, four types of cells' mutations are understood to contribute to development of cancer [5]. These four types of mutations are explained to students with enough details to offer understanding of the problem and the opportunity to develop at least a starting point in building a meaningful model for prediction of cancer given a current state of a patient.

Since the prediction of cancer is an ongoing long term project in medicine, the students are not expected to build the entire model, but rather brainstorm about possible approaches, and consider limitations of particular techniques through simulation of the system on a smaller scale.

Since many cell mutations remain unexplained nowadays, students are faced with a somewhat random generation of mutations. Based on the existing literature on cell mutations, it is not known when a mutation will occur. However, the rate at which each mutation occurs is well-studied and documented. Thus, even though the mutations are random, the students need to simulate these mutations taking into consideration the estimated rates of each mutation.

While students' models of cancer growth will necessarily be simplistic, students will be exposed to key concepts and will be familiar with the dynamism of such systems and how they are studied.

IV. Comparison to Old Curriculum

In the past, CompSE (then titled CPSE) was taught as a traditional introductory computer science course, which focused on teaching students the syntax and semantics of C programming language. While learning basic concepts of programming is of great importance, it also could be boring for students who do not plan to major in computer science.

Because of the focus on syntax and semantics, traditional programming courses are organized around programming concepts such as input and output, branching and loop statements, and often objects. Lab assignments for these courses are selected in accordance to the topic that was just learned, and are often hypothetical or very simplified real-life problems. Students are often faced with using computer programming to solve problems that could easily be solved with pen and paper, a calculator, or a simple spread sheet, thus not getting the right feel for the importance of programming and computer science in general.

Moreover, programming is often taught without mentioning limitations of certain programming language or limitations of programming in general. Students are only introduced to viable concepts and asked to solve problems whose solutions could be obtained in a straightforward manner.

In contrast to the previously taught curriculum of a traditional introductory programming course, which focuses on syntax of a language, the new curriculum for CompSE offers a more problem-oriented approach to learning programming concepts. As described in the previous section, the focus of the new curriculum of CompSE is on introducing students to behavior of dynamic systems. A system is studied in phases starting from its simplified versions to more complex and more realistic behaviors. Besides learning programming tools, students also learn different dynamic systems, some of which come from their fields of study. Students are introduced to a variety of dynamic behaviors, some more stable than others, and are expected to transfer this knowledge and experience to other non-programming courses that they take.

Unlike traditional methods for teaching programming, students in the CompSE course face limitations of programming and simulation techniques. They realize that not everything could be simulated exactly as it happens in reality, and learn how to set reasonable assumptions. In the second half of the semester, students are also forced to determine which of the learned techniques suits best a given problem.

Similarly to the old curriculum of the CPSE course, CompSE covers all basic programming concepts. However, these concepts are not taught to just show to students that these particular tools exist, which is often the case in traditionally taught curriculum. Computer programming concepts in CompSE are taught when needed to solve a particular problem, and thus clearly show to students the need, usage, and implementation of these concepts.

V. Expected Learning Outcomes

Anticipated learning outcomes of CompSE include mastery of basic programming concepts, deeper understanding of the dynamics of real-life systems, understanding of common simulation techniques, and interest in continued study of computational systems.

Since it is currently almost impossible to study, understand, and analyze dynamic systems without the aid of computers, one of the main goals of CompSE is to involve a larger number of students from various disciplines in computational sciences. By providing a more problem-oriented approach to teaching introductory programming, CompSE examines examples that are more related to attendees' field of study. Thus, the expectation is that the new curriculum will not only attract a larger number of students to study the first course in programming, but also increase the interest of these students to continue enrolling in computing classes.

Moreover, CompSE aims at improving students' understanding of real-life dynamic systems by the use of computer simulations. Since simulations allow students to quickly evaluate the impact of different parameters in a model, the behavior of dynamic systems is better understood by experiments. Furthermore, students are challenged to develop these simulations on their own, thus a thorough understanding of the dynamic system at hand is needed.

Even though the focus of CompSE is on modeling dynamic systems, basic computer programming skills are covered in this course. They are introduced through simulation of dynamic systems under reasonable simplifying assumptions. The complexity of computer programming is gradually increased through addition of layers of complexity of the dynamic system at hand.

Students are exposed to different modeling and simulation techniques. As an outcome of this course, students should have a good understanding of the advantages and disadvantages of different modeling techniques with respect to their accuracy, simplicity, and speed. Students are also expected to understand the benefits and drawbacks of small scale simulations of large dynamic systems as well as limitations faced during simulation phase.

VI. Evaluation

Our planned evaluation will examine both the effectiveness of the course in achieving student learning objectives, and student interest in continuing multi-disciplinary studies that include computation and programming.

The main student learning objectives include mastery of basic programming skills, understanding underlying concepts of dynamic systems, learning simulation techniques along with their limitations, and ability to use simulations to solve problems that are hard or even impossible to solve using only analytical techniques. The achievement of these objectives will be measured by applying in-class examinations as well as several lab assignments in which the students will be challenged to work through problems that have not seen yet and which are selected from different disciplines.

Students' interest in continued study of computation will be measured by pre- and post- class online surveys. These surveys will measure:

- Students' beliefs that computation is necessary in their field.
- Students' confidence that they have enough programming skills to write programs relevant to their fields.
- Students' confidence that they can learn (if not already possess) programming skills relevant to their fields.
- Students' confidence about understanding dynamic systems, and
- Whether students intend to take more computing courses.

The comparison of students' answers at the beginning and the end of the semester will determine the change of students' attitudes towards CompSE and other computation courses. These surveys and analysis of surveys will be prepared and applied in collaboration with an external evaluator.

Moreover, we will track down the students from CompSE classes to find out whether they have taken any additional computation classes after completion of our CompSE course.

VII. Synopsis

CompSE is an introductory computer science class for non-computer science majors. Unlike the previous curriculum it replaced, CompSE uses a problem-oriented discovery learning approach to programming and understanding dynamic systems. This approach is expected to attract students from various majors and stimulate their interest in continuing the study of computation. Moreover, the students are expected to learn basic concepts of programming, and understand the basic principles of dynamic systems and simulation techniques.

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Engaging Weak Programmers in Problem Solving

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Abstract— **As with many schools attracting international students, our postgraduate degrees must cater for students with diverse backgrounds and skill-levels. It is not practical to accurately assess students' domain-skills prior to enrollment. Thus, we found a need for a compulsory bridging course with the dual objectives of improving the problem solving and programming skills of the weakest computer graduates whilst still challenging and improving the skills of experienced programmers. This paper describes our experience in refining such a course over six semesters, in order to meet these goals.**

Keywords: collaborative learning, programming, problem solving, self-reflection

I. INTRODUCTION

Like many computing schools exposed to the international market our school attracts students from a diversity of backgrounds and skill levels. The diversity of skills is most apparent in our postgraduate coursework students with many having good theoretical knowledge but lacking in practical programming skills. To address this weakness, we developed a compulsory course (named Specialised Programming) to be taken by all starting Masters students. The main challenge for this course was to help weaker programmers to reach a satisfactory level while also challenging and improving the skills of the more experienced programmers.

Inspired by ideas from Astrachan[1] in first year undergraduate teaching, we based our course on practical application of programming to small, but realistic, TopCoder[2][1] problems. To cater for our cohort, we modified his approach in two key aspects:

- the use of cooperative learning strategies[3] to support the transfer of skills between students.
- course assessment based *primarily* on graded sets of these realistic problems, to better assess and directly address specific deficiencies in problem-solving skill sets.

Although other courses use subsets of TopCoder problems to replace/extend coding assignments, our course aims to improve the programming skills of postgraduates by intensive practice at solving these problems. The design of this course is informed by principles of deliberate practice[4,5]: skill acquisition is based on high repetition, designed practice, with fast feedback, tailored to individual abilities. The requirement for fast feedback means that errors should be identified and corrected during practice. The acquisition of expert performance through deliberate practice typically takes years [5, 6] so we cannot produce expert programmers in a 12-week teaching semester. However, we should expect to see a measurable improvement in student programming skills, which may provide self-motivation for further practice.

This article describes our experience with presenting this course over six semesters and in particular the impact of a number of changes made at the start of 2009 based on the experience of students with weaker programming skills.

The remainder of this article is structured as follows. Section II describes the course structure followed by the results and insights made during its delivery in 2007 and 2008 in Section III. Section IV lists the changes proposed at the start of 2009 in order to engage weaker programmers. Section V shows the impact that changes made on performance, particularly on the bottom half of the class., followed by a summary of what we have learned in the process.

II. COURSE STRUCTURE

The course presentation consists of lectures, structured group practice sessions, and ad-hoc tutorial sessions as needed. Except where stated, the following description of course structure applies to all six semesters that have been presented so far. Refinements to this framework over time are defined in subsequent sections.

Lectures are run in two-hour weekly sessions presenting algorithmic techniques for various problem types, based on the textbook "The design and Analysis of Algorithms" by Anany Levitin. The end of each session is typically devoted to supervised programming practice.

Three hours of each week are devoted to either practical exams or structured group practice sessions. The group practice sessions offer a mix of new and familiar problem types. Each group, of approximately four students, is assigned one or more problems. After working on the problems for 60 to 90 minutes, a group representative is picked to present their algorithmic solutions to the rest of the class. Coding and submission is to be completed independently by each student after the practical session. A summary of the problems selected for each session is provided at [7].

Each TopCoder problem statement has a consistent style, starting with a precise and entertaining description of the problem; followed by a description of the class name and

[1] Questions used, with permission, from TopCoder Inc.

method signature required; input data constraints; and, finally, some sample input and output data. Hints are rarely given in problem statements and there are usually many good ways to answer each problem allowing room for creativity.

Testing sets for each problem are harvested from TopCoder data using scripts and converted into a Java driver program to be used in the School's automatic submission system. During submission, students get feedback on the number of test cases they passed and for the first test case they fail they are given the input and expected output. They can resubmit their code as often as needed.

Groups are initially allocated in week 2, based on the result of a diagnostic practical exam using a genetic-grouping algorithm, to maintain diversity of skill levels within groups and uniformity between groups. Group allocations may be modified based on the performance up until the mid semester break.

Students are expected to practice outside of class time. They are encouraged to practice problem-solving with their group, but code their solutions individually. Group work makes the experience less threatening and decreased isolation.

Assessment is primarily based on practical exam performance with smaller amounts of marks allocated to group participation. Assessment begins with a diagnostic exam early in the semester followed by practical exams every 2-3 weeks. The minimum requirement for a passing grade will be to solve at least one problem in each exam. The submission system remains active at all times and students are able to practice submitting any question from the practice sessions or previous exam sessions as part of their practice regime.

Practical exams are hosted in a reasonably secure online environment. During the practical exams, students' normal accounts are suspended and practical exam accounts activated. Network controls are put in place to restrict access in the laboratory only to the school web pages, the submission system, and individual subversion accounts, in which the students place answers to be harvested by the submission system.

Each practical exam consists of three problems of differing degrees of difficulty. The first problem would require simple algorithm techniques (i.e. sorting, searching, string manipulation) and basic knowledge of the java API (documentation for which is available on-line during the exam). The other two problems will use the techniques taught during lectures (i.e. brute force, greedy, recursion, dynamic programming). The exam time is set to 3 hours, including the reading time (compared to 75 minutes for a Top Coder competition), so there is time to correct and modify the solutions, although a student needs to be a good programmer to solve all three problems in that time.

III. Initial Results

In this section we describe the outcomes of the first four offerings of the course in 2007 and 2008 in terms of three areas: assessed results; the quantity and quality of student practice; and student performance in exams. We describe each of these in turn.

A. *Assessed Results*

All four initial offerings enjoyed reasonable success with almost all students being able to solve at least the simple problems and achieve a passing grade.

As an indication of the initial ability of each cohort, Table I shows the performance of students in the diagnostic exam for the six consecutive semesters it has been taught. The problems in the diagnostic exam cover a range of the basic problem solving schemes and we would expect a graduate student with average Java programming skills to solve two problems. In all intakes, there was wide range of programming skills.

TABLE I. Student Performance on the Diagnostic Exam

Problems Solved	**2007**		**2008**		**2009**	
	S1	**S2**	**S1**	**S2**	**S1**	**S2**
0	17%	18%	42%	22%	71%	40%
1	8%	12%	33%	11%	12%	30%
2	25%	18%	17%	41%	12%	20%
3	50%	53%	8%	26%	6%	10%
	original course				after changes	

The first cohort of the course and, to a lesser extent, the second cohort contained a number of students who were reasonably competent programmers with enthusiasm for problem-solving. These offerings worked well for these students, with several commenting positively on the opportunity to be challenged and learn new skills. The ability of these cohorts was, in part, reflected by a high number of credit and distinction grades in the first two semesters.

In 2008 the average skill of the cohort dropped significantly. This can be attributed to the fact that, 37% of students who enrolled in Semester 1, 2008 had deferred enrolment in that course during 2007. Similarly, the Semester 2, 2008 intake had 27 student of which 8 have already deferred enrolment at least once. In other words, the weakest programmers delayed taking this course until the end of their programs (the program rules made the course compulsory but did not enforce pre-requisites, so it could be taken any semester). The data for 2009 is included in Table I as a basis for later comparison.

Students initially lacking programming skills could solve few problems during their diagnostic exam and struggled to both solve and code simple problems in practical exams. The apparent causes of these problems varied. Some have issues understanding the problem descriptions but with help they were able to code the solutions on their own. Others had little experience with Java and needed help to process any non-trivial inputs values. Others had difficulty debugging. To address these problems we provided ad-hoc tutorial support for those who felt they needed it.

Student skill levels in each semester improved from the diagnostic, with low failure rates below 10% in all semesters (without including, as we will discuss later, those who failed due to cheating in 2008). Although some students showed low performance in the first two practical exams, as they improved on later exams they were offered a supplementary exam.

B. Student Practice

Practice is the core activity in this course and students were encouraged to practice individually and in groups on a broad range of problems. Over 5000 individual practice submission attempts have been made by the 93 students who have taken this course over the four semesters Practice problems, of graduated difficultly are set up in the same way as the exam problems. Students can access practice problems on the web and submit multiple times without penalty. In addition, previous exam problems remain online as an additional pool of practice problems.

Due to the limited time in supervised practical sessions, the last step of problem solving - the coding of the algorithm - is left for the students to do outside the class at their own pace. Unsurprisingly, the volume of practice undertaken outside of class varied considerably between students. Fig. 1 plots, for each student in each semester, the number of practice attempts in the automatic submission system versus the number of attempts achieving a 100% score.

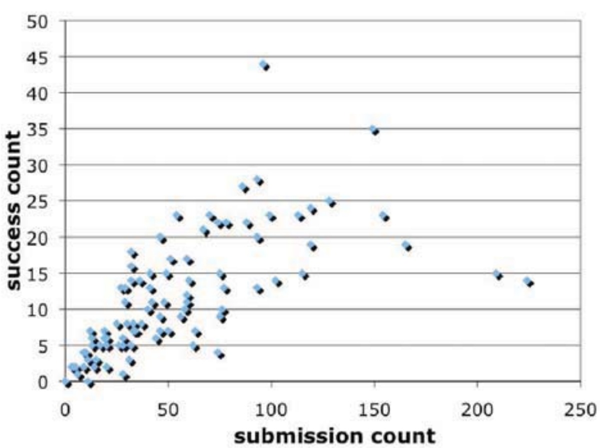

Figure 1. Number of practice problem attempts versus number of practice problems solved (2007-2008)

The plot shows that most students make about four total attempts for each successful attempt. This is not unexpected, even seasoned programmers sometimes fail to anticipate some test cases or make minor errors in their code requiring multiple submissions. The plot also shows the number of attempts made and the number of problems solved is highly correlated (correlation coefficient = 0.67) indicating that in most cases intensive practice is rewarded with a reasonable amount of success (or, conversely, that success encourages more practice). Last, but importantly, the plot shows that most students make less than 50 practice submissions solving less than ten problems – well below our recommended practice to students to solve 1 or 2 problem questions each week in a 12-week teaching semester.

Another observation about practice is that students did not practice consistently throughout the semester. Fig. 2 illustrates this issue in the 2008 semester 2 instance of the course. We observed students doing practice problems in the first few weeks leading to the first practical exam at the end of teaching week 4, but after that the amount of practice declines to very low levels in the second half of the course. This is in spite of the fact that that 3 of the 5 practical exams, which might benefit from practice, are held later in the semester.

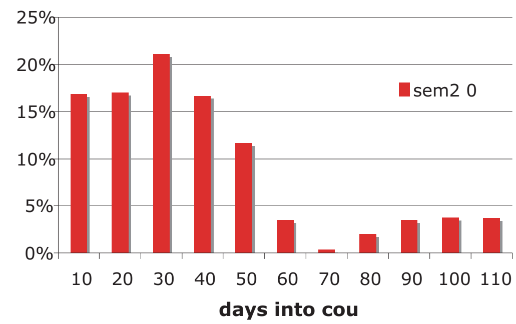

Figure 2. Histogram of practice submissions over duration of the semester 2 2008 course.

Motivation for practice also varied considerably between students. This variance was anticipated and, in the original design of the course, group members shared a proportion of their exam marks to create some of the positive interdependence needed for cooperative learning [8] and reduce the propensity for social-loafing [9]. Unfortunately, in the first instance of the course, a significant proportion of students - aiming for a bare pass - optimized their level of practice to the detriment of other group members. So, in the interest of fairness, the sharing of marks was quickly withdrawn under a no-disadvantage rule.

So far, we have seen that the amount of practice and the motivation for practice varies between students and across time. What about the impact of this practice on exam performance? As might be expected, the number of practice problems solved, by individuals is correlated with the number of exam problems solved by those individuals. Fig. 3 plots these metrics for each student in each semester. The maximum number of exam problems it is possible to solve in a semester is 15 (three problems in each of five practical exams).

The correlation between practice problems solved and exam problems solved (correlation coefficient = 0.34) is weaker than the relationship between practice submissions and practice success. This weaker relationships might be attributed to a number of factors: the time limit in the exam gives students more limited scope for experimentation; exam conditions restrict access to resources that may help with problem completion; some experienced students didn’t practice and simply turned up to the exams; some students aimed for a bare pass; and, finally, a minority cheated.

These *in-exam* performance factors bear closer scrutiny, thus next section will explore some of these aspects.

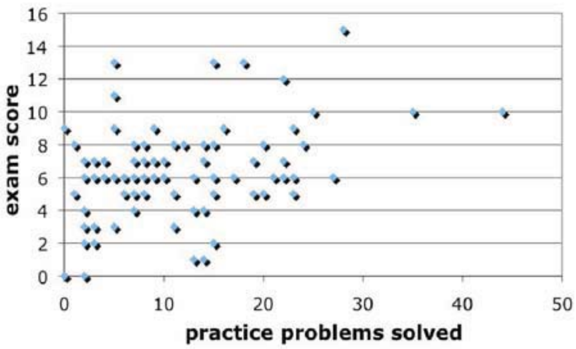

Figure 3. Number of practice problem solvedversus number of exam problems solved (2007-2008)

C. Student Exam Performance

In this section we describe aspects of student behaviour and performance during practical exams. In general, students are more prone to rush in the exams than during regular practice until they have solved the first problem, which keeps them in the pass range.

When submitting a coded solution, the student receives immediate feedback on the number of test cases passed, and when incorrect it can see the first test case failed and the expected output. For some students this feedback is sufficient to refine/correct their code, but weaker programmers spend most exam time fixing failed input cases one by one, breaking working parts of the code in the process. Their final solutions are longer that needed, and as the problems get harder, they cannot produce a working solution for all cases.

We present here as an example the analysis of the submitted solution for the problem *BoxesofBook*s, during a practical exam in semester 2, 2008. A solution to this problem requires a simple loop to iterate over the array of books to be packed into boxes, returning the number of boxed needed, and the overall code should take 20-25 lines at most (reducible to 15 lines if you don't use nice layouts). Good coders solved the problem in a short time interval, within 3 attempts or less and their code size was as expected. Other coders took longer and although they solved the problem their final solutions were complicated and their code size went up to 30-45 lines. As expected, later submissions increased code size; in only *one* case a submission reduced the code size, after the student worked out he was going in the wrong direction.

Four students (out of a class of 27) were not able to solve the *BoxesofBook*s problem. Two of them started with a reasonable solution but they keep adding code to solve each case and ended up with 50 and 82 lines respectively. One of the students submitted 23 attempts, with only a few minutes between them. Another student keep changing conditions within the loop but could not correct their code after 13 attempts.

The extent of this problem of repeated attempts is apparent in Fig. 4, which plots the number of exam submissions made by each student in each semester against the number of successful exam submissions for that student. The plot shows a worryingly low success rate for some students with, in one case, over 166 submissions for 3 questions solved.

The anatomy of successful and failing exam attempts is analysed in Fig. 5, which contrasts the pattern of attempts for exam problems leading to success (881 successful attempts) with those leading to failure (423 eventual failed attempts). As can be seen, most successful attempts at questions take three or less submissions to get it right. Failed attempts tail off considerably more slowly. Worryingly, more than 5% of failed attempts have more than 15 submissions. These high counts almost always indicate that a student is re-submitting by making minor unproductive changes in a desperate attempt to pass the automatic testing. We label this unproductive behaviour in practical exams as thrashing.

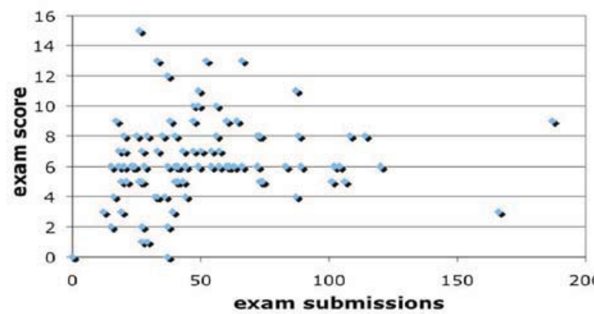

Figure 4. Plot of number of exam submissions made versus number of exam problems solved (2007-2008).

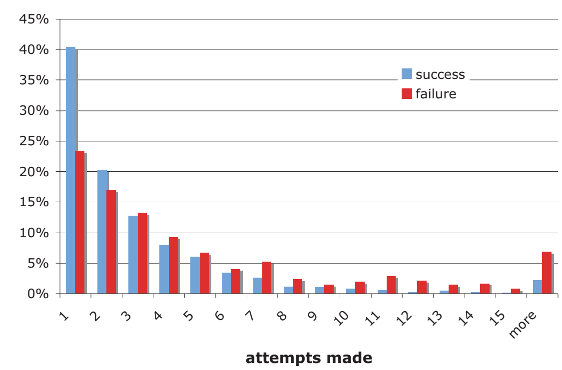

Figure 5. Histogram of submission patterns for successful and failed attempts at exam questions.

The impact of thrashing is significant. Given a conservative threshold for thrashing of three or more unproductive attempts in less than 15 minutes, 30% of the nearly 6000 submissions made in practical exams are instances of thrashing. As an aside, not every instance of multiple closely spaced attempts at a question constitute thrashing.

A small number of, eventually, successful attempts take a very large number of submissions. Sometimes a large number of submissions stems from an attempt to pass the automatic testing by the tactic of: (1) failing a case (2) harvesting the expected output value (3) inserting a print statement of the expected output value and (4) then resubmitting to harvest the next value and so on. Given that the number of test cases is usually high, in the range 60-120, the effort required for this tactic is considerable[2].

Because so much thrashing was occurring in exams and, to a lesser extent, during practice we decided to investigate this pattern more closely. In some practical exams we observed the weaker students attempted the first problem and after a few attempts to fix their code they gave up and move to the next problem. Again, they were able to produce a draft solution that passed the trivial cases but were not able to fix their code in order to pass the non-trivial cases. As the end of the exam approached, they panicked and jumped from one problem back to the other one, editing their code but their corrections were not well thought through. For example, they would panic and reverse the condition of a correct *if* statement to see if that passed more tests.

It is not surprising, given the pressure to complete their masters program, that some students resorted to cheating during practical exams. In Semester 1 2008, 10% of students failed due to documented cheating, although there was other doubtful cases which avoided being failed, due to the complexity of detecting and proving cheating as discussed in [10]. Although we have removed the submissions identified in any cheating incidents before analyzing the data, there is some doubt on the real performance of some students under different exam conditions for semester 1, 2008. Simple measures were taken to make cheating more difficult and the rates of suspected cheating have fallen in 2009.

Finally, two common behaviours for less-skilled programmers were a passive role in their group practice and diminishing attendance lectures as the material moved on to address more advanced concepts.

D. *Insights 2008 intake*

At the end of 2008, we reflected on the performance of the struggling students compared with those who thrived and gained the following insight:

> *All students were able to sketch a feasible solution for most types of simple problems. But weak programmers often overlooked one or two boundary cases and, thus, they failed some test and they were not able to identify the causes of their failure.*

We will list below the list of factors that prevent weaker students from solving non-trivial problem:

- Lack of debugging skills: although students do use debugging tools and print statements to find what their code is doing, they are slow in both indentifying the line(s) of code that are causing the problem and the changes needed to fix it. This is general caused by limited programming practice.
- Poor coding style: they code monolithic solutions, and rarely define additional methods to simplify coding and testing. For example, given a string manipulation problem in which they need to identify vowels, they would not define a method called *isVowel(*char x), instead they repeated the code needed to detect this condition as many times as needed.
- When their code fails after several changes, students are reluctant to go back and work through their solution on paper or change their strategy, as they felt this would take too long.

[2] And for naught - these cases are manually detected and given zero marks.

IV. CHANGES TO ENGAGE WEAKER PROGRAMMERS

This section will report the changes to the course delivery aimed at keep less-skilled programmers engaged, by addressing the set of problems identified above.

A. *Introduction to problem-solving*

From the analysis done, it was clear the course pace was too steep for those with low programming and problem solving skills.

The textbook assumed good programming skills and skipped over the range of problems that need simple algorithmic skills (sorting, searching, string manipulation, simple maths). Therefore, there was no support for the weaker student that lacked basic problem-solving skills. In other cases, students were not familiar with the Java API so they wrote their own code instead of using simple methods (such as *Maths.min* or *Array.sort*) to process the data.

So, the first change was to extend the coverage of basic problems types from one to three lectures. The additional time allowed to provide more examples and to describe ways to identify each basic problem type. Through the examples, we emphasized the need to reference to the Java API to find methods that may simplify coding. For example, when describing a string manipulation problem that uses prefixes we asked students to go through the String class and find methods that may be useful (such as *startsWith).*

B. *Step-by step problem-solving*

Weaker students write their code without prior testing of their strategy and made limited use of the given examples provided to see if their code will work.

To emphasize the need to devise a basic algorithm, we introduced a paper problem template, with sections to identify the problem type, write the basic idea of how to solve it, and then convert it into an algorithm. This template was provided at each lecture time, and we asked students to work on the template before coding the solution on the terminal. Instead of moving to the labs to do a problem-solving session at the end of each lecture, we ran them in the lecture room, forcing them to write their solutions on the template. We also introduced in the first practical session techniques to test the examples on paper, so we can see if the algorithm works for the examples given before coding it. The additional teaching materials and modified lecture schedule are provided in [7] for the interested reader.

These changes, combined with some one-on-one coaching, helped most students to focus on doing some development and testing of algorithms prior to coding.

C. Increase group practice and feedback

Another major goal to keep weaker programmers engaged was to enforce problem-solving practice every week, particularly on the second half of the semester. To achieve this, we ask each member of a group to fill an online report weekly, from week 4 onwards, describing the list of problems attempted and/or solved and the way the group tackled them. The report format is shown in Fig. 6. Each weekly report was worth 1% of the final mark (9% in total).

Although the reports are not compulsory, each student must complete at least 40% of each of three course components (1.practical exams, 2.practical sessions and 3,group reports) to avoid a failing grade.

By asking them to list the Java classes and methods used to solve problems, we reinforce each week the need to check and use the Java API. Thus, there is a minimum practice required outside the practical exam, which is monitored by the weekly reports. The second question provides feedback to lecturers on group dynamics, and by having to report on it, we encourage weaker students to participate in their groups. The last question encourages self-reflection so that each student could identify and assess the strategies they were using.

1. *List the problems you attempted, your scores so far for each problem, and which Java API Classes and methods you used to solve each problem. Remember that you must attempt at least two different questions each week. For example:*

   SlowKeyBoard: 90 out of 90

   - ArrayList (size, add, get)

   - Arrays.sort

   .

   FracCount: 7 out 100

   - HashMap (containsKey, put, get)

   - ArrayList (size, add, get, remove)

2. *Describe what happened during your group practice session. Who contributed and how did they help the group? Highlight the things that went well and/or any problems that arose.*

3. *Which steps of the problem solving process did you find easy?*

   Which steps did you struggle with?

   What approaches did you use to overcome those difficulties?

   Can you think of how you might approach the problem differently if you had to start again?

Figure 6. Weekly Group Report online questions.

We are able to provide feedback to their self-reflection when marking the reports. This refinement and review process is aligned with other methodologies for addressing problem solving in Computer Science [11].

In the first semester 2009 we focused on feedback and self-reflection, but noticed some students were claiming to complete problems they did not have submissions for. To counter this, in the second semester we policed their submissions and sometimes reminded them of the need to code their own solutions.

The weekly reports were also useful for the lecturers by providing feedback during the course on the topics and issues than students find more difficult so that teaching materials could be adjusted accordingly.

V. RESULTS

The new course structure has been used in both semesters on 2009. In this section we will evaluate the impact that the changes had both on regular practice and student performance.

There was some anecdotal evidence from two students repeating the course in Semester 1, 2009 that the gentle introduction to problem solving made the course content less scary; the examples provided in lectures were a good start to review the java API, and students felt more confident before taking their first practical exam in week 4.

We should note 2008 had the largest cohorts (36 and 27 students for semester 1 and 2 respectively) while 2009 had small cohorts (19 and 10 students). Particularly, students in the last cohort had nowhere to hide, they received more feedback and the chances of cheating being undetected were much reduced. In fact, two students cheated in the first practical exam, but as they exam results were so different from their class performance, they were easily identified and they decided to drop the course, so they are not included in the study.

A. Problem solving practice

The changes of the course encourage students to keep practicing during the whole semester. Groups meet outside the supervised practical session to solve problems and the weekly reports provide feedback of the interaction in the group. In the second semester, groups were more active. Although there where some issues with students who did not participate, 80% of the student agreed that working in a group was a valuable experience.

Fig. 7 shows number of practice problem submissions per student per term in 2009 versus the number of problems actually solved. The old 2007/2008 data from Fig. 1 is included for reference. Success rates in 2009 are similar to 2007/2008 but the average amount of practice per student is slightly higher and the correlation between practice attempts and practice success is higher (0.90, up from 0.67) this is partially due to there being fewer students getting little reward from their practice attempts.

This better success rate also appears to be reflected in exams. Fig. 8 plots the number of exam submissions per student per term in 2009 versus the number of problems solved in exams. The old 2007/2008 data from Fig. 4 is included for reference.

The plot shows that there are comparatively few students making many submissions with limited success. This is also borne out in the higher correlation between exam submissions and exam success in 2009 (0.76) than in 2007/2009 (0.51). Overall, the amount of thrashing in exams was reduced.

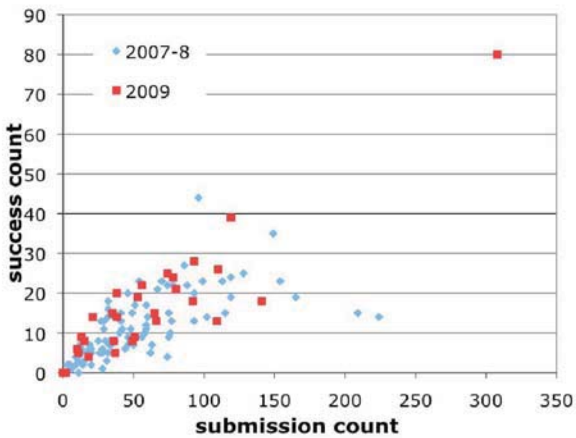

Figure 7. Number of practice problems attempted versus the number of practice problems solved in 2009 (2007-2008) data included for reference.

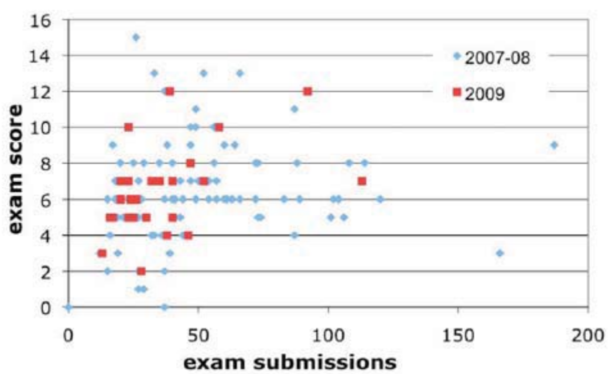

Figure 8. Number of exam submissions made versus the number of exam problems solved in 2009 (2007-2008) data included for reference.

Practice habits also improved somewhat in 2009. Fig. 9 shows the amount of practice over the semester for semesters 1 and 2 of 2009 with the data for semester 2 of 2008 from Fig 2. included for reference. Some improvement in second half practice is apparent.

Table II shows the number of problems solved both during practice and during the exam for all students who remain enrolled for the whole semester. We should note that we can only measure practice done using our submission system, which may be lower than expected if students practiced at the TopCoder website. Our local problem pool had approximately 40 problems in 2007, and grew by 15 problems each semester, so in the latest semester there are more than a 100 problems to choose from. Only two out of 10 students in the last semester reported using TopCoder to source additional problems.

The rise on problem-solving practice is more pronounced in semester 2, as we reminded students on the need to code their solutions via the report feedback. Consequently, the number of problems solved raised to 20 - within course expectations as they must submit 9 weekly reports, in each of them they should report on solving two problems. As the problem sets in the practical sessions become harder, some students choose to solve problems from previous year's practical exams[3], which is in line with deliberate practice.

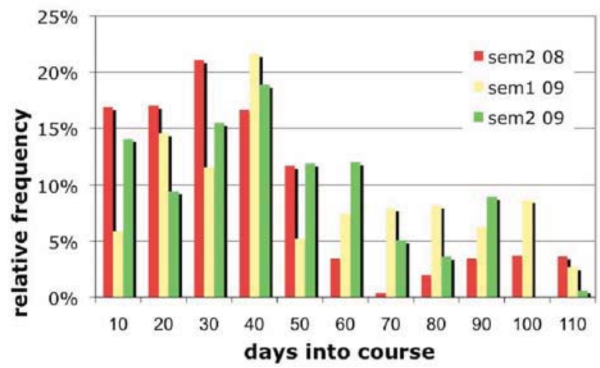

Figure 9. New practice patterns in 2009 as compared to semester 2 2008.

TABLE II. AVERAGE PER-PERSON SCORES

Average per-person	2007 S1	2007 S2	2008 S1	2008 S2	2009 S1	2009 S2
Practice attempts	80	41	53	48	55	77
Practice solved	11	9	13	12	14	20
Exam Attempts	54	38	58	44	37	32
Exam solved	6	5	8	6	6	7
Course Score	71	62	63	51	65	67
	original course				after changes	

B. *Exam performance*

Row four of table II shows the number of problems solved during practical exams. The number of problems solved is a good indicator of performance, although the higher value in 2008 S1 is a possible reflection of the cheating problems that were detected in the middle of the course.

We can see the number of exam attempts is lower in 2009 compared to 2008, this is an indication of reduced thrashing.

[3] In all our analyses we count these attempts at old exams as practice attempts rather than exam attempts.

It is difficult to measure class coding speed as each problem set may be more or less challenging depending on the type of problem chosen and the Java skill-set required. Figure 10 compares the speed to solve the first problem for three consecutive cohorts, one before the changes to the course, and two after. To reflect the problem complexity we chose the second fastest solution in each exam as representative of the top of the class and compared that time with the time needed by the bottom half of the class. We measured the speed of the bottom half of the class using two metrics:

- *half-solved* is the average time taken by those in the bottom half of the class who manage to solve the problem
- *half-all* consider that those who did not complete will take at least 3 hours to do so, and include them in the average.

Thus, a higher half-all (the green bar) compared to the half-solved (red bar) indicates some students failed to pass that exam. We can see this is the case in all exams in semester 2, 2008, except for exam 3.

The exam performance for the bottom half of the class was, in general, better in both semesters of 2009. Students in semester 1 did not show significant improvement compared to the previous cohort, but considering their initial low skills (please, refer to Table I), there was a clear improvement as the semester progressed. At the end of the semester all students were confident they could solve at least one problem, which may have also helped to keep them calm and do better.

Although exam difficulty is variable, we can see that the difference in speed between the best coders and the bottom of the class is narrowed in the last semester. The best performance in 2008-S2 was for exam3, problem 1, when all but one student solved the first problem. The question was simple and it took 13 minutes for the second fastest coder, and the slowest one took 2 hours and 46 minutes. A similar type question was used in 2009-S2 exam 5, and as the figure shows, it also took 13 minutes for the second fastest coder, but the average for the bottom half was 28 minutes and the slowest student took only 37 minutes.

We believe there were two reasons why the last cohort solved some problems faster:

1. they were able to identify the problem type (brute force) as they read the problem description,
2. they needed less time to debug/correct their code.

We should note than in exams 3 and 5 of semester 2, 2009, all students managed to complete the first and second questions, compared with exam 2 in which 3 students could not solve one problem. Exam 4 had a harder first problem but most students were able to complete it.

There is also evidence in the practical sessions that students became better at problem-solving, and could identify the problem type and some basic algorithms to be applied. However, their problem-solving skills were ahead of their Java programming skills so they could not code their solutions.

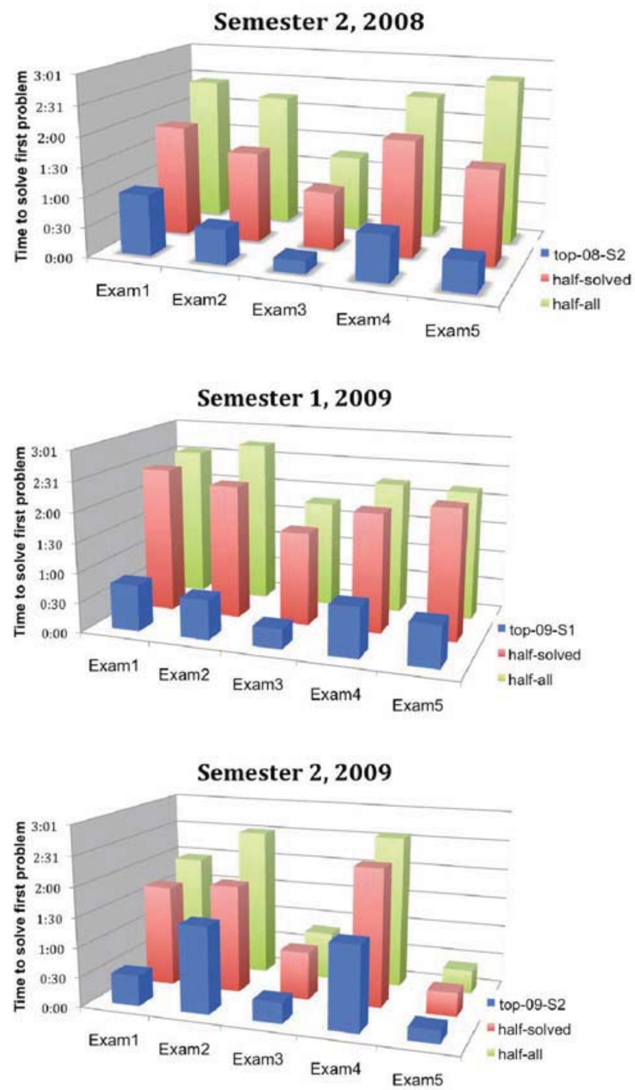

Figure 10. Time to solve the first problem at a practical exam, for 3 consecutive semesters.

In particular, they found hard dealing with complex input data that needed to be stored in another format to simplify coding of the solution. For example, the textbook and the course lectures cover graph algorithms such as Breadth Search First in detail. In the last practice session many students could work out that the given problem could be solved by (1) building the graph and (2) finding the shortest path from a given node to another. But only 3 out of 10 students were able to construct a graph from the given input information. Thus, we need to add more support material for the second part of the course to support coding for complex problems.

C. *Student feedback*

As expected, the better class performance in semester 2, 2009 is accompanied by positive feedback from the small group of students who took the course. We will report here on some of the comment received and their suggestions for further improvement.

All students agreed the course have improved their problem-solving skills and their ability to work independently. Below are two quotes (printed with permission) from students that show we have achieved one of our main goals by providing the programming skills needed for their Master degree:

"During the initial stages I took 90-120 minutes to solve a single above problem. But now I take 30-60 minutes to solve the problems. SP eased me in doing assignments of Computer Vision, which are actually very tough to do"

"Although most of the tasks for this course have been finished, I still need to keep on practicing, since I have noticed that the practice we have done during the whole semester really helps me with coding and debugging"

All students thought the practical sessions have a good mix of problem types and they were positive about working is a group. One student suggested including peer-review on their coding as part of the group work. Antoher student made the following suggestion:

"My only problem was that some of my group members wouldn't attend group meetings. The course could have a forum that listed weekly group attends, and how many times you met outside your Practice Sessions to work on problems. That way, people might feel more accountable to attending group sessions".

During the course, most students reflected on their weekly reports on their need to work on pen and paper to check if their idea worked before coding. In the course feedback, a student reported on the importance of developing an algorithm first:

"The real power of the problem solving process comes down to pen and paper - first test out the examples on paper, by trying to "solve" the problem. Then try and figure out what you are doing to solve the problem. Make sure that you have examined all the EXTREME cases, base cases, boundary cases, before you implement it."

However, during exam time some students skipped this step and coded straight to the terminal with variable success. Thus, we need to do more work to reinforce this concept.

VI. Conclusions

We believe the strategies used in this course, based on aspects of deliberate practice [4], would be applicable to other technical courses with mixed cohorts.

Students are more likely to improve their skills if we provide clear expectations of what is needed to reach each grade level, and encourage the practice needed to achieve good grades.

It is important to assess students' initial skills in the first week, in order to help target support for the weaker students. We should note the review of basic techniques and debugging skills is also useful for stronger students, as it encourages self-reflection and good practice. Most students respond positively when they see some improvement early on the course.

By identifying the factors that cause failure and monitoring student performance, we could provide a tailored process for each student to achieve their objectives. The group reports provide good feedback on individual progress and chances to tailor their practice but this may be too onerous on the lecturer for a large cohort. As one of the main benefits of the reports was self-reflection, we will consider using blogs as a tool for students to report and reflect on their progress.

Future work on this course will focus on bringing more aspects of deliberate practice into the learning process including the selection of more questions designed to find and address particular skill deficiencies and more infrastructure to lecturers to monitor each student's progress and, just as importantly, to allow students to monitor their own progress.

Acknowledgments

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Portugol IDE v3.x

A new environment to teach and learn computer programming

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***Abstract*— Teaching of programming is crucial in every engineering course and particularly in computer courses. Students failure in this domain has led to the development of Portugol IDE, a tool for teaching/learning algorithms. This tool allows algorithms to be coded in mother tongue of portuguese students (portugol) or in flow diagrammatic language (flowchart) and its automatic execution. This paper presents generation 3.x of this tool and describes the advancements therein.**

Keywords-component; programming learning; portugol; flowchart; computer science education

I. Introduction

All courses in computer science related areas include in their curricula an introductory module on programming, which usually has high rates of failure. The concepts taught in this introductory module will be used in many other course disciplines and the rates of failure are deemed as one of the major reasons for student drop-out from these courses [1] [2] [3].

This serious drop-out rate has been a subject for research and several recommendations from computing professional associations (e. g. ACM e IEEE) [3]. Many different strategies and tools have been proposed to improve the teaching/learning process of programming basics [1]. With this in mind, faculty members and students of the School of Technology of the Polytechnic of Tomar have developed an innovative environment for teaching/learning algorithms - Portugol IDE.

This freeware and open source environment has been used in the Polytechnic of Tomar, in national and foreign higher education institutions and in high schools and professional schools.

Given its success and in order to broaden its scope of application in the teaching of programming, the authors have developed generation 3.x which features a more advanced language and a new environment.

This paper includes an overview of this tool (Portugol IDE) and the pedagogical characteristics that make generation 3.x an asset for the teaching of programming.

II. Portugol IDE project

Portugol IDE is an environment for algorithm exploration designed for the teaching of programming created in the Polytechnic of Tomar in 2005 as the final project by finalist students of the degree in Computer Engineering. This teaching/learning tool is available free of charge (http://www.dei.estt.ipt.pt/portugol) and its source code is accessed through the GPL licence. The tool has been developed using Java technology which makes it transferable to any computer platform that supports this technology.

Portugol IDE uses a Portuguese lexicon-based language for encoding algorithms (the portugol) and a graphic language (flowchart). These languages have been defined in a manner that allows their execution by the computer and are equivalent among them [4].

Flowcharts are a graphic language consisting of parameterized geometric shapes and arrows representing the flow of execution between those shapes. As it is a graphic language, the algorithm is designed and thus form parameters have a minimal syntax, thus being less prone to coding errors. This language is specially intended to teach the foundations of computer programming. Figure 1 shows the Euclid's algorithm coded in portugol and in flowchart.

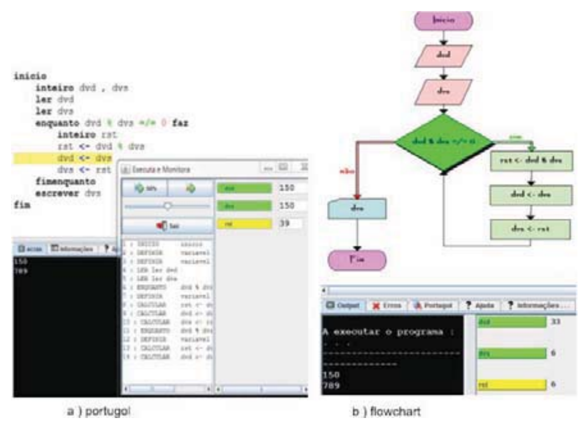

Figure 1. Euclid's algoritm in portugol (a) and flowchart (b) executed in the Portugol IDE environment.

Portugol has a small set of instructions and operators with a flexible syntax which make it easily understandable and powerful enough to perform complex reasoning. Although the flowchart is executed through portugol language, it is transparent by the student.

Portugol IDE also has some features that improve the efficiency of the programming learning process. Its environment allows the students to encode, execute and check algorithm correction in an iterative way within a simple intuitive environment (Figure 1). These activities can be performed in both languages and the system allows the translation of the algorithm into the complementary form providing an alternative representation of it. The environment allows formal verification of the algorithm through step-by-step execution of computer instructions. Portugol IDE also allows visualization of the state of real-time memory variables and to control algorithm execution speed. By analyzing automatic execution of the algorithm the students can recognize algorithm correction or the instructions that make it incorrect. Thus students can execute, change, correct and test their theories to solve the problem contributing to an active experience-based learning.

III. PORTUGOL IDE V 3.X

Advancements in Portugol IDE have reflected the needs and suggestions from faculty and students regularly invited to contribute to its development both at the level of system encoding and at the level of introduction of new tool features. This symbiosis between the two parts of the teaching/learning process causes Portugol IDE to be a widely used and appreciated tool by the whole academic community in the Polytechnic of Tomar.

The first generation of Portugol IDE was developed in 2005. The second generation was launched in 2006 and was characterized by the introduction of the flowchart module and its inclusion in portugol language. The generation 3.x of Portugol IDE featuring an enhanced language and a new environment will soon be launched

Previous generation of Portugol IDE was designed to teach learning modules: data manipulation, decision structures and repetition structures. For this purpose basic data types and arrays have been defined.

A. Core Enhancements

New features of generation 3.x include the possibility of defining complex data for the tuition of algorithms involving the definition of the arrangement for conceptual data (structures).

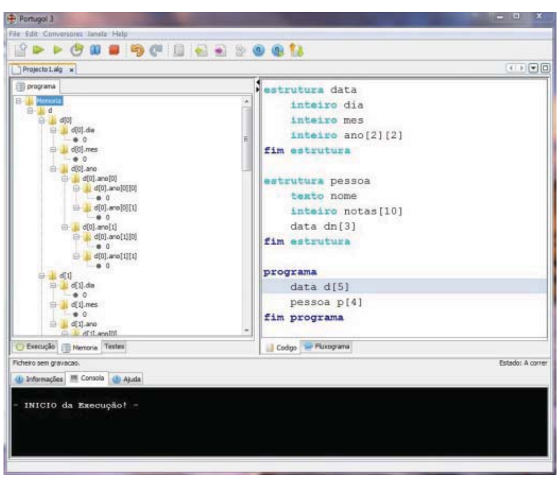

Figure 2. Complex data types in Portugol IDE v 3.x

The concept of reference is one of the most complex issues of computer programming [5]. Today this is introduced to students through complex computer languages such as C making learning of this subject even more difficult.

In order to illustrate this concept within the Portugol IDE environment, a new feature (&) has been introduced in variable definition to support values or addresses. Manipulation of the referenced variables follows a pattern that is similar to that of normal variables in which memory operations are displayed in the learning environment as can be observed in the referenced variable pb whose attribution value is like a normal variables (figure 3).

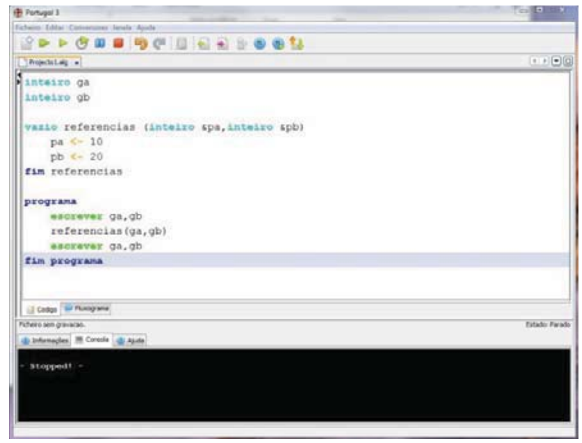

Figure 3. References in Portugol IDE v 3.x.

The new generation of Portugol IDE was equipped with a feature that allows the use and definition of iterative and recursive functions. Function definition enables problems to be divided into several modules that can be solved separately thus allowing new techniques for the development of algorithms to be learned such as top-down and divide-to-conquer.

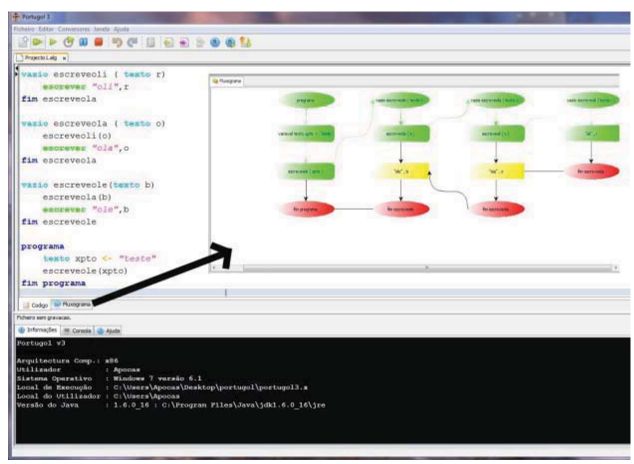

Figure 4. Functions in Portugol IDE v 3.x in the form of portugol and flowchart

The ability to include Java-compiled function libraries enables the utilisation of the learning environment in pedagogical contexts which were not initially predicted. These libraries can be developed by the students and external contributors so as to increase the functionalities of Portugol IDE without putting at risk the stability of the tool.

B. Development Environment

Classroom context is hazardous to any software because there is, more than often, an intensive unpredicted use of it.

To equip the tool with a sound basis an RCP (Rich Client Platform) architecture has been used. This type of architecture is very powerful due to its modular structure which is constituted by a nucleus containing several modules surrounding it and provides different features. As nucleus the NetBeans Platform RCP by Sun has been used. The stability of Portugol IDE nucleus has thus been ensured through a platform whose code has repeatedly been tested for years in IDE NetBeans, that shares this same platform.

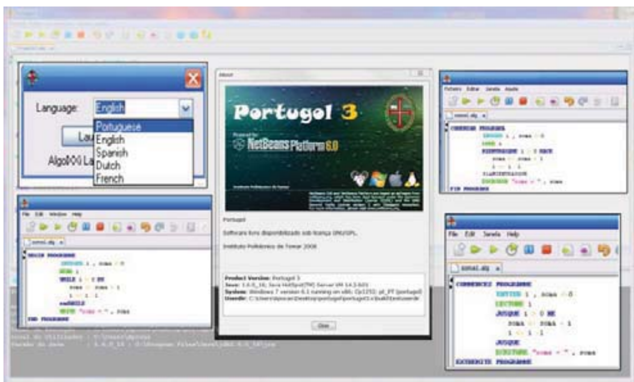

Figure 5. Multi-language suport of the Portugol IDE v 3.x

Previous generations of Portugol IDE have only been made available in Portuguese, this feature being hardcoded in the source application code, which made implementation of a new language very difficult. In Portugol IDE v3.x the interface language can be changed in a dynamic way as well as the language used in the source code syntax written by the student. Thus the students with different mother tongues will always write in their natural language. The source code in all the languages is the same, and the tool have an intelligent module that identifies the language of the source code and translates it to the desired language. This feature allows the exchange algorithm regardless of the language they were written.

This feature allows the coexistence of different language-speaking students in the same classroom solving the same exercises and cooperating among them.

In order to implement functions and complex data types it was necessary to redesign the overall system used to represent both local and global memories. The tree layout has revealed to be the best way to represent complex data structures allowing the user to collapse and expand different memory levels, thus turning the representation more organised and understandable (Figure 2).

To represent the different memories (global and local) a tabbed interface has been used in which each memory has an independent tab with a tree layout in the inside as can be observed in Figure 7. Tabulations of local memories are added and removed according to program execution. Only active local memories and the global memory are visualised.

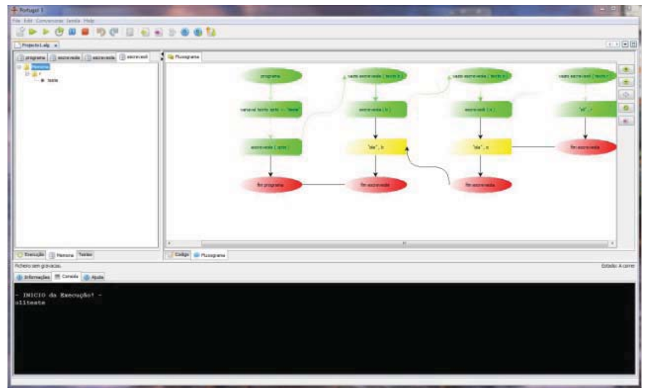

Figure 6. Running the algorithm in Portugol IDE v 3.x

To implement the new language features in flowchart no new graphic elements have been introduced, thus maintaining easiness. In function call, the process icon functionalities have been redefined in which execution of a function starts the construction of a new flowchart for the execution of the algorithm implemented therein. The transfer function parameters are now represented in the start icon and the return value in the end icon.

This new functionality generates a new local memory which in turn is generated by the start icon and destroyed by the end icon.

IV. EDUCATIONAL APPLICATION

Portugol IDE allows the student to be more active in the learning process, improves the effectiveness of development and verification of algorithms and promotes algorithmic reasoning.

Portugol IDE is currently being used in Engineering degrees and vocational programmes of the Polytechnic of Tomar, in various higher education institutions of the Portuguese-speaking community (e.g. Integrated Regional University and UDF – Brazil University Centre) and in several high schools (e.g. Sertã and Foz Côa High Schools).

In order to assess Portugol IDE's capacities, i.e. its utility and usability, a survey has been carried out involving students attending the 1st year of the Computer Engineering programme in the School of Technology of the Polytechnic of Tomar [1]. The participants have revealed to be very pleased with Portugol IDE viewing its innovations as extremely useful to learn programming. They also consider this learning environment as effective, user-friendly and easy remindable.

We believe that with launching of version 3.0 Portugol IDE has made great progress and advancements. This version allows the use of iterative and recursive structures and functions. With this functionality students will be able to learn more complex study contents in a simpler way.

The easy change of interface application language and the language used in the source code syntax enables the students with different mother tongues to always write in their natural language. Portugol IDE generation 3.x promotes algorithm distribution through learning management systems and Web repositories.

With this enhanced version it will be necessary to know the behaviour of future users. We intend to collect students opinions about Portugol IDE 3.0 and also to assess the implications of this new version in learning by carrying out a quasi-experimental survey [6] involving two different groups: Group A (use of Portugol IDE 3.0) and Group B (use of traditional table tests)

V. CONCLUSIONS

Learning how to program is a complex task involving high levels of abstraction and logical thinking which, as a rule, has high rates of failure.

Portugol IDE has been designed in a manner as a support tool for teaching and learning the basic foundations of programming. The definition of a minimal set of instructions for portugol and flowchart languages facilitates the learning of commands and icons but they are also sufficiently powerful to construct complex algorithms.

Furthermore, generation 3.x. of Portugol IDE also allows to define complex data types, to use iterative and recursive functions, to include Java-compiled function libraries, to change the language of application interface and the syntax language, to represent different memories, among other functionalities.

We believe that Portugol IDE is a good option for all those who are involved in the teaching/learning of programming as it facilitates active learning inside and outside the classroom environment while it validates algorithms, facilitates error depuration and supports two languages: portugol and flowchart [7]. Instructors are no longer the holders of the solution and become more available to their students.

New features are already being studied with the aim of promoting a virtual ecosystem in the framework of Portugol IDE, including its articulation with learning management systems, learning content management systems and learning objects repositories.

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A Study and a Proposal of a Collaborative and Competitive Learning Methodology

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Abstract— **Competition is evident throughout our society, lives and work. "It transcends time and place, as well as all manners of people". In this paper, we present a study and a framework proposal for a mixed collaborative-competitive learning environment, applied to a programming course in a University level engineering program. While neither collaboration, nor competition, is inherently good or bad in supporting the learning process, the way teachers employ these strategies in classrooms determines their value in preparing "soon-to-be" professionals. We believe this mixed-based learning approach best serves students as they are able to achieve academic success both in working with others and on an individual basis. Besides the traditional theoretical lessons and laboratory practices of the course, the integration of the framework automates all the support and evaluation processes. It implements both an individual competitive setting and a collaborative one, where intergroup competition occurs, by means of two interconnected modules. We discuss our results and findings in its preliminary use, concluding that the framework promises to have a good impact in the way we teach some programming courses in our Institute.**

Keywords-competitive learning; collaborative learning; programming language innovation; automated evaluation framework.

I. INTRODUCTION

Competition is evident throughout our society, lives and work. "It transcends time and place, as well as all manners of people" [1]. In this matter, Universities play an essential role in preparing students for their professional lives, and courses should be adapted to an increasingly competitive and challenging world outside of them. Therefore, although different teaching/learning methods and styles exist nowadays, we emphasize, and describe in the current work, teaching as a mixed collaborative-competitive setting.

While neither collaboration nor competition is inherently good or bad in supporting the learning process, the way teachers employ these strategies in classrooms determines their value in preparing "soon-to-be" professionals [2]. An effective classroom must have the right mix of cooperative learning and competitive learning (along with individualized learning) [3]. This mixed-based learning approach best serves students as they are able to achieve academic success, both in working with others and on an individual basis, enhancing learning opportunities for students pursuing a professional career [4]. These two learning techniques do relate to the workplace of our times. Often in the business world people work on a variety of team settings, thus, collaborative activities in a classroom can prepare students for the experience of their professional lives. With these activities, students may also engage in learning because they enjoy cooperating with others. Similar to a collaborative structure, employing competitive learning has a complementary potential to engage students. Once they are faced against each other, their competitive instincts can encourage them to increase their commitment towards the learning process. Even students who initially may not be inspired by the subjects may begin to be interested once they have to compete. We also believe that this is particularly useful for students who are not prone to be competitive, since they should be confronted with this reality as soon as possible.

This work presents a study and a methodology proposal for a collaborative and competitive learning setting. It is based on a computational framework currently being under development for a programming course on a Polytechnic Institute engineering program. This methodology relates to learning in competition with others, achieving individual goals with or without collaboration from peers [5, 6]. Besides the usual theoretical lessons and laboratory practices, the integration of the framework in the course automates all the support and evaluation processes. It implements two competitive settings instantiated by the Champions League (CL) module and the Automated Test and Group Ranking (ATGR) module. The first module targets an individualized type of competitive learning, where students are selected to participate in a tournament with a group stage and a knock-out phase, similarly to the well-known UEFA Champions League. The later module aims at an intergroup competitive setting, in which balanced student groups are formed, competing among them. A third module is predicted to be implemented in the future, where the actual programs coded by the students compete in an arena, but its scope of applicability isn't as broader as the other two – only in artificial intelligence-like programming courses – and will not be further discussed in this paper.

The paper is structured as follows: in Section II we report some related work and studies with competitive and collaborative learning, while the methodology and supporting framework are presented in Section III. In the following section, we discuss our findings and present student opinions for this methodology, based on empirical and questionnaire results. Finally, in Section V, overall conclusions are taken and future work is presented.

II. Related Work

Concrete, reflective, abstract, experiential and active learning are some terms used to describe alternative pedagogical methods that fit different learning styles. Hence, there are several learning styles proposals and mixed applications described in literature [3, 7]. Obviously, learning styles are individual preferences and tendencies that influence the learning process [8]. Johnson and Johnson [3] refer a close relationship between learning styles and attitudes towards learning, including motivation to learn, involvement in learning activities, attitudes towards teachers and self efficacy. Students learn better if contents are presented to them through a medium that matches their preferred learning style [3, 7, 9]. Moreover, independently of the area of knowledge, recent innovations in pedagogical techniques have led to the introduction of new instructional methods in the classroom. These innovations include, for example, educational and on-line games [10, 11], asynchronous instruction (e.g., email, electronic bulletin boards and podcasting) and computer-based teaching [12]. Therefore, the different learning approaches are basically applied by teachers according to their experiences, the ambience where they find themselves teaching and the concepts they want to pass through.

Based in our experience in teaching programming courses, we have found that a mixed collaborative and competitive method is an adequate approach for such courses. Competition has been defined as “a social process that occurs when rewards are given to people based on the basis of how their performances compare to the performances of others doing the same task or participating in the same event” [13]. Competitive learning holds both positive and negative aspects. Lam et al. [14] found that competition had a positive impact on performance goals and learning motivation in the classroom. Also, it has been stated that “learning by loosing” was a valuable process for students preparing themselves for professions where working under pressure was necessary [15]. On the other hand, some handicaps related to competitive learning have been identified in literature, like high anxiety levels, self-doubt, selfishness and the interference with the capacity to solve problems [3]. Nonetheless, these issues can be attenuated if one establishes different competing environments, being one of them the competition between groups of students, during which elements of a group cooperate in achieving personal goals, hereby introducing collaborative learning. Collaboration, or cooperation, has been defined has “a social process through which performance is evaluated and rewarded in terms of the collective achievement of a group of people working together to reach a particular goal” [13]. As with competition, collaboration also yields positive and negative aspects. Duetsch [16] suggested that collaboration embodies positive interdependence and found that college students solved more problems in a collaborative environment than students in a competitive environment. The main problem that we identify with collaborative learning is the possibility of an uneven engagement in learning by individual students within a group, translated into uneven contributions for the group's final grade. Nevertheless, with our methodology, the individual merit of a student can be assessed in the individual competitive setting.

Programming courses offer good conditions for the implementation of a competitive environment, based on both collaborative and individualized learning. Structuring a problem-based competitive project, wherein collaborative student teams compete against each other, is a way by which teachers can ensure both collaborative and competitive learning opportunities for students [4]. These methods have also previously been applied to other engineering classrooms [17, 18, 19].

Previously to the work presented in this paper, some experiences of learning through competition and collaboration were carried out in our Institute. The implementation of a market based on software agents was the main goal of a curricular innovation experience in an advanced course on Distributed Artificial Intelligence [20]. The task was prepared to enhance the learning experience through collaboration and competition among the students. The project involved the creation of a community of agents capable of modelling a market of goods and competences. For each producer agent (with reasoning capabilities implemented by a group of students), the goal was to maximize its production capabilities and earn more money, by means of competition with other producer agents. This proved to establish a rich and challenging collaborative-competitive environment for the students, supported by their opinion and developed works. In another case of competitive learning evaluation, groups of students were asked to implement a representation of the horse game, the game operators (piece movements) and a search algorithm. The horse game is a simple game that finds its origin in the chess game and is played by two individuals on a ten per ten square boards. Essentially, the groups of students would play against each other and the first tree ranked groups of the tournament would benefit from a bonus translated into a higher subject grade. The introduction of the competitive element in the course motivated the groups to care and look for better implementations of their programs. By testing them against each other, they automatically started to explore new heuristics and to improve their algorithm's implementation to get better results in the competition.

As for related frameworks, *Mooshak* [21] is the only one we know about and is interesting because it presents some similarities with modules and functionalities of our proposal. *Mooshak* is originally a system for managing programming contests on the Web and its basic features include automatic judging of submitted programs, answering to clarification questions about problem descriptions, re-evaluation of programs, and tracking printouts. The system was originally intended for contests, but it is increasingly being used in programming courses, used to give instant feedback on practical classes, to receive and validate assignments submissions and to partially evaluate and mark assignments.

However, in competitive programming field there are several examples on the web like *Robocode* [22], *Top Coder* [23] and *ProjectEuler.net* [24]. *Robocode* is a game where a programmer codes the behaviour of a robot that is put into battle with others around the world. *Top Coder* is more targeted for professionals, since competition happens with programmers solving problems for customers and getting paid for the job in case they win. Finally, *ProjectEuler.net* is composed of hundreds of mathematical problems in which computer programming skills are required to solve the majority of them. By solving one problem it will expose the programmer to a new concept that allows him to undertake a previously inaccessible problem. So, a determined participant will slowly, but surely, work his way through every problem [24]. We find this interesting because the idea is similar to our “hints” mechanism in the proposed framework (next Section).

III. Methodology and Framework

This section details the methodology proposed, highlighting the main principles, the supporting computational framework’s architecture and the development of the two competitive modules. The followed learning methodology implementation is explained along with the framework’s architecture and modules description.

A. Main Principles Requirements

When implementing a new methodology and designing a framework like the one presented with this work, we first establish guidelines for the design. Some principles requirements that must be regarded in the conception of our proposal are the following:

a) To implement different competitive learning settings (competitive and collaborative), but with a strong interdependence between them;

b) To insure flexibility with regard to time and location, the framework should be available in a permanent manner, i.e. anywhere, anytime;

c) To present teaching and assessment materials in a language that is simple, clear, direct, adequate and attractive to the target for which the courses are intended;

d) To create auto-evaluation functionalities, in the form of evaluative exercises and tests that allow students to evaluate their own progress;

e) To continue introducing a variety of competitive components, such as games and challenges, to stimulate the student to engage with the learning solution;

f) To allow, in case of failure, the repetition of the studying process as well as the practice and auto-evaluation, yet with a different set of exercises;

g) To use the information obtained from evaluation moments and every time students use the system to define measures that allow guaranteeing the existence of an adequate component of support and feedback from the system and from teachers;

h) To devise adequate analysis that allows teachers to become familiar with students who are really learning from this methodology.

B. Overall Architecture

The framework supports a methodology divided in two different competitive settings. As mentioned in the Introduction, these settings are mapped into two modules of the architecture (Fig. 1) – the Champions League (CL) and the Automated Test and Group Ranking (ATGR).

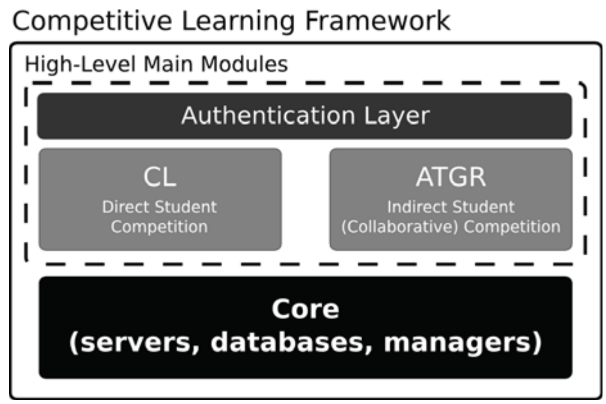

Figure 1. Overall architecture of the presented framework.

The CL module implements an individualized type of competitive learning, while the ATGR module is related with intergroup competition where collaboration occurs within groups. An Authentication Layer, for controlling the access to the system, is an independent module because it depends on the information system used at the Institute. This way, we do not keep duplicate information about users, but instead use the information already available in the information system, e.g. student's number, name, course, number of enrolments, etc. It is only necessary to map the users’ unique identification on that system to the information stored in this learning framework.

These high-level modules are strongly interdependent, not only because they are used in conjunction to evaluate and to teach the students, but also because the results taken from the CL are used to configure groups in the ATGR module. The groups of students are generated upon results from the CL to ensure homogeneous grouping, maximizing the chance of winning for all groups. Homogeneous grouping allows the groups to be as evenly matched as possible to provide a challenging environment for competition. We discuss this grouping methodology in Section IV. Therefore, the output from a module is used as input on other modules, despite being used in an indirect way. This means that the output data from a module must be stored in the core of the system.

The core is composed by the necessary servers, like web and database servers, and the manager modules, which are used to configure the system to a learning case. This configuration is made by advanced users, e.g. teachers with an administrator course role, who determine exactly how to apply the proposed methodology through the supporting framework.

In addition, the framework also integrates contents modules for the lessons and for the students study, being a complement for the competitive learning. These modules have a strong emphasis on multimedia contents with audio, video and animations. They are presented through web interfaces and a multimedia interactive DVD-Rom.

C. The Champions League (CL) Module

The first main module implements a competition where the students are selected to participate in a tournament similar to the well known UEFA® football Champions League (CL), with a group stage and knock-out rounds. The architecture for this module includes four main sub-modules (Fig. 2).

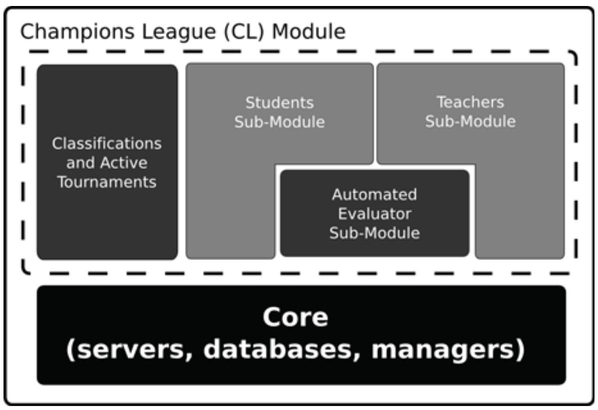

Figure 2. Detailed architecture of the Champions League (CL) module.

One of them is the manager of Classifications and Active Tournaments (CAT). All the information is gathered from the corresponding database. The CAT module is a Web-based application where it is possible to get information about past and present competitions. Students have access only to data related with competitions where they have participated. Teachers can export results from competitions designated as assessments, which are configured according with that. In short, it presents tournaments classifications and matches results, detailing the obtained goals for each student player, and statistics that can be obtained through a set of queries.

The module related with teachers integrates all the functionalities necessary for the correct management of the competitions. One teacher can add new exercises, with the corresponding type descriptors, to the database and configure CL tournaments, which may be of the formative or assessment type. Through this sub-module, teachers access the Automated Evaluator (AE) sub-module, configuring it according to the class of students they have in mind to compete. Additionally, this module has access to another sub-module integrated in the CAT module. Through it, teachers can determine which and how results and statistics data should be presented to students, with the possibility to decide if they are made public.

The AE module crosses the submitted results (programs resolutions) with the configuration made by teachers and the exercises descriptors taken from the database to evaluate how many goals were achieved by each student in the scheduled match. Each exercise has a set of goals to be achieved that are specified by a teacher when submits them to the database.

For the competition, students use the laboratory computers to implement the proposed code for each programming exercise (a "match"), where they compete against an opponent and the clock. Using the Students sub-module, students must submit a file with the implemented code to the framework at the final of a match, or when they finalize it. They also have to use this Students module to access their areas in the CAT module.

The AE module automatically evaluates the obtained results of the matches, updating the repository and giving feedback to the participants. Briefly, the result of a match is dependent on the evaluation of each exercise resolution submitted by each student that participates in the match. When a submitted exercise is evaluated, the number of goals obtained by the student is counted and stored. This is important information not only for statistic purposes, but also for course evaluation purposes. If both students obtain the same number of goals, then it is necessary to look up for the timestamp relative to the moment when files were last saved. If this item is also equal then the match result is a draw, resulting in one point for each container, otherwise, three points for winner and nothing for the loser.

The competition can take place for several sessions (lessons, marked days, etc.) and a teacher can configure it by choosing, for example, the starting time of the different group games, the level of the games (exercises to be implemented), the submission type, the competition mode (auto-evaluation/training, assessment, or friendly), among other parameters.

In addition, another sub-module under development will permit that students submit to the database exercises to be implemented by their colleagues in a determined CL competition. This is one of the most interesting functionalities in our methodology, since we think this may improve the learning performance of a student, as he has to find and know adequate exercises for accomplishing this specific task. Although not necessary, this can be a parameter in an evaluation.

D. Automated Test and Group Ranking (ATGR) Module

This module is responsible for automatically evaluating the correct implementation of functionalities within a final course project. The module architecture is depicted in Fig. 3.

One advantage of this module is that it relieves teachers from manually testing each group project, which can be very time-consuming, particularly in courses that easily scale up to hundreds of students. This way, they only have to complement the automatic evaluation by evaluating the quality of the code produced by the groups of students. The second advantage is that student groups may use the system to do periodic checks to their implementations and see if they are doing things right, i.e. if their algorithms are producing the correct results. While doing so, they are competing with the other groups for being the first to achieve correct implementations of the different functionalities/tasks that compose the overall problem assigned to them. During this process, they are awarded points for a correct implementation, plus bonus points for being the first, second or third groups to achieve each individual goal.

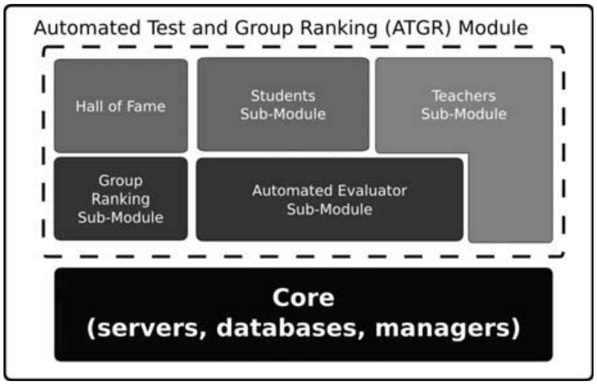

Figure 3. Architecture of the Automated Test and Group Ranking (ATGR) module.

As an incentive, each time a group submits a correct implementation, for a particular functionality, they receive clues ("hints") for solving other harder functionalities. At the end of the submissions – the deadline – the final ranking table (Hall of Fame) elects a winner group to whom is given a bonus grade, as well as to second and third runners-up. Nevertheless, the ranking table is available to the students throughout the implementation phase as a means of direct competition.

In order to sort out if some kind of plagiarism or code-sharing occurred, all final implementations are submitted to the Moss system [25], a software plagiarism system from Stanford University, upon which a Hall of Shame can be generated. This list is not a priority to us, but in severe cases it must be used and it can even act as a deterrent measure for future course editions, or for other Institute courses.

The front-end of the sub-modules that interact with users are web-based. In order to avoid abuse, teachers are responsible for group information submissions and assign themselves to those groups, using the Teachers module. Through this sub-module teachers also upload the code, which will be used for automated testing of project implementations, to the Automated Evaluator sub-module, in the same way they do for a CL competition. Authenticated groups (any student assigned to the group can do so) submit their implementations code through the Students specific sub-module. After that, they can obtain feedback from the AE sub-module, including the aforementioned clues for solving what is left of the problem.

The Hall of Fame sub-module is responsible for retrieving the information from the database and for generating the rankings table. When the delivery deadline is reached, all the final versions submitted are sent to the Moss server and results can be made public. All data relative to group performance, submission history and rankings are stored in a specific-module database, with modularity in mind, at the core.

IV. RESULTS AND DISCUSSION

In this section, we summarize and discuss our findings and student opinions during this early use of the proposed methodology and supporting computational framework. These experiences were conducted with laboratory classes of an introductory Java programming course. The final grading of this subject is calculated by summing 50% of the exam grade (written exams cannot have a weight inferior to this percentage in our Institute) and 50% of the grade provided by the framework adding its two settings.

A. *The CL Pilot Experience*

In terms of the competitive learning provided by the CL module, the results obtained with the first application of the methodology were very positive. Students thought it was a very interesting initiative, giving to them some fine moments where they were able to combine the concerns of an assessment with the joy of participating in a game. Not exactly the feelings to expect from an evaluation moment, but they were much nearer of situations from the real World. For teachers, it clearly showed them that better prepared students were the ones obtaining the best results in the final classification.

Pool A					
G1	Texugo's Team	6	-	5	Net_Azelha Beta
	Cova Piedade	2	-	5	Java The One
G2	Texugo's Team	4	-	1	Cova Piedade
	Net_Azelha Beta	4	-	1	Java The One
G3	Java The One	0	-	0	Texugo's Team
	Cova Piedade	0	-	3	Net_Azelha Beta
G4	Net_Azelha Beta	4	-	3	Texugo's Team
	Java The One	1	-	1	Cova Piedade
G5	Texugo's Team	4	-	2	Cova Piedade
	Net_Azelha Beta	4	-	2	Java The One
G6	Java The One	0	-	1	Texugo's Team
	Cova Piedade	0	-	4	Net_Azelha Beta

Pool B					
G1	Rosado	7	-	4	Lello
	Valongo	4	-	2	Pereira AC
G2	Rosado	4	-	2	Valongo
	Lello	3	-	1	Pereira AC
G3	Pereira AC	0	-	0	Rosado
	Valongo	0	-	1	Lello
G4	Lello	2	-	1	Rosado
	Pereira AC	1	-	2	Valongo
G5	Rosado	1	-	1	Valongo
	Lello	2	-	3	Pereira AC
G6	Pereira AC	0	-	1	Rosado
	Valongo	1	-	1	Lello

Pools Classifications						
Pool A	W	*D*	*L*	*GF*	*GA*	*Points*
Net_Azelha Beta	5	0	1	24	12	15
Texugo's Team	4	1	1	18	12	13
Java The One	1	2	3	9	12	5
Cova Piedade	0	1	5	6	21	1
Pool B	W	*D*	*L*	*GF*	*GA*	*Points*
Rosado	3	2	1	14	9	11
Lello	3	1	2	13	13	10
Valongo	2	2	2	10	10	8
Pereira AC	1	1	4	7	12	4

Final Phase					
SF - G1	Texugo's Team	3	-	1	Rosado
	Lello	1	-	3	Net_Azelha Beta
SF - G2	Rosado	2	-	4	Texugo's Team
	Net_Azelha Beta	5	-	2	Lello
Final	Texugo's Team	3	-	5	Net_Azelha Beta

Figure 4. First CL edition results. Legend: G (Group), W (Wins), D (Draws), L (Losses), GF (obtained Goals), GA (suffered Goals), SF (Semi-Final).

As an example for an easy understanding, it is possible to analyse a small laboratory class of eight students that took place in the first CL edition. Fig. 4 presents the competition progression with all the obtained results.

First, it is important to summarize how students got placed in the groups/pools and the organization of the competition. They were split into two groups of four students/teams (each student chose a team name to relieve the pressure of competition and evaluation), who played "home" and "away" against each of their pool opponents to decide which two teams from each pool would advance to the first knock-out round. In these rounds, the last 16 until the semi-finals, teams played two matches against each other on a "home" and "away" basis. In this case, after the groups stage we ended up with only four teams, the best two from each pool. So, the first round was not the last 16, but immediately the semi-finals round, and group winners played against runners-up other than teams from their own group. In this application, it was not necessary to make a draw because the number of participants was limited. The final game was decided by a single match.

The tournament results help to understand the reason why the student with the team name "Net_Azelha Beta" won the competition. Besides being the winner of her pool, this student also "scored" the highest number of goals after six games played, considering that the games/exercises were the same for the two pools. "Net_Azelha Beta" has reached a total of 24 programming goals present in six proposed exercises. It was an excellent result since it was above 95% of the goals represented by the six Java programming exercises. However, the same appreciation can be made for the second best team. Moreover, the course final written exams proved that the semi-finalists students in this CL edition were really the best students of their class. This is an important conclusion because it proves that a competitive learning environment does not prejudice the best students.

After the realization of the competition, with duration of approximately one month and five laboratory lessons, we also carried out a questionnaire survey. It was carried out among all the students in order to determine their satisfaction and opinions regarding the CL competition. The questionnaire was designed to gather information on students' attitudes towards aspects of the competitive learning they experienced as well as towards some more specific aspects of testing. The questionnaire had six questions:

1. How much do you like it?
2. How useful is it?
3. How much pressure do you feel when participating?
4. How fair is it?
5. How much do you want to maintain this CL format?
6. How functional is the CL module of the framework?

Students had to answer with a number that ranged between 1 (a little) and 5 (a lot) for each question. In Table I we present the mean value of the ratings on each question.

TABLE I. STUDENT'S OPINION QUESTIONNAIRE ABOUT CL MODULE

Students	Questions					
	Q1	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*
Testing Class	4,62	4,88	5	4,88	4,75	4,62
All Classes	4,37	4,63	4,82	4,55	4,13	4,67

One row of the Table I has the questionnaire results from the eight students of the previous CL example, while the second row refers to the answers from all students (60) of all classes. We believe that these results traduce perfectly what the CL competitive methodology brought to the course: "more demanding with more fun".

Moreover, in the classrooms, teachers felt that students were positive about the introduction of this evaluation method and the questionnaire results confirm that informal and empirical conclusion.

B. *The ATGR Module Application Example*

In regard to the collaborative setting – intergroup competition – the reception by the students was also positive. One of the features they liked the most was the possibility of checking their implementations at home in an autonomous way, rather than just believing that it was correct with their own testing or with the help of teachers.

One of the first things to be set in the ATGR module, besides preparing it for a particular course project, is the composition of the groups. Initially, it is common for students to be somewhat reluctant to being assigned into groups. However, explaining to them that employees in an organization rarely get to choose their co-workers and are often put in situations where they have to work with people they do not know, the students come to understand, accept and benefit from the situation. We first thought in achieving balanced groups, in terms of chance in winning the competition, by pairing the first ranked student in the CL competition with the last, the second with the next-to-last and so on. But soon we found out that this was not the correct approach, because some students would be concern about being paired with an underachiever or that did not have good results in the CL competition. A purely random composition of the groups is preferred [4]. However, upon this random composition process, we used the information gathered from the CL competition, along with our own knowledge about the students, to correct the composition of some groups when we detected that the original ones did not benefit them or the competition. Our main concern is to engage all groups in a healthy competition, even if it happens separately in clusters of those groups.

The competition begins after the groups have been set. One of the interesting things we concluded was that it turns out that it is not beneficial to let the students make all the submissions they want to the framework. This is a negative side-effect that we must take into account for the following courses and competitions. It leads to a kind of frantic development by which they do not reason about what is wrong with their code, but embrace a trial-and-error approach until the system tells that their implementation is correct. In a few cases, it really became a game of fortune. We believe this is not desirable and we chose to limit the number of permitted submissions per-day, e.g. five submissions. This forces the students to use them wisely and also prevents them from reaching a correct algorithm "by chance" in the hurry of being the first ones to implement that functionality.

The students enjoyed the "hints" provided by the system during their submissions. They found them particularly useful to overcome the harder functionalities implementation as they approached the submission deadlines. Teachers liked the automatic evaluation of the projects since they are able to know beforehand the different levels of completion of each project. This is also particularly useful in giving grades, because students immediately have a tangible way of comparing their expected grades with others. All of this is obtained at the expense of a greater workload on behalf of the teachers during the initial setup of the framework for a particular course, but we believe that it is compensated during all the teaching/evaluating process and provides a rich and challenging environment to students for learning and preparing themselves for their professional lives.

V. Conclusions and Future Work

In this paper we presented a study and a proposal for a collaborative and competitive learning methodology, applied to a university level programming course. Due to an increasingly competitive professional world, where at the same time people are put to work with others in teams, we provide a mixed setting between these two learning methodologies with the expectation that it will somewhat prepare them to their professional careers, as well as providing a rich and challenging learning environment.

Opinions gathered form students during the initial use of the methodology and supporting framework were positive and we have discussed our findings and suggestions for such systems. In summary, these preliminary results showed us that this kind of mixed competitive-collaborative learning methodology has the potential to become a solid and reliable approach in learning programming languages. We believe that the developed framework is a valuable tool for the support of both teaching and learning activities. It will have a key impact on how some programming courses are taught in our Institute.

The modules presented for the framework have been implemented, but separately, and are now being integrated and unified in the proposed framework. This obviously leads to some refinements in modules that were independent, particularly in terms of a uniformed user interface, a common authentication layer and database sharing. Depending on the internal success of this framework, we intend to release it as an open-source project so others may benefit from it while, at the same time, helping in the process of perfecting it and/or adding new features.

As future work, a third module that targets artificial intelligence-like courses is planned, whereas the students' actual implementations of some projects will be put into an arena to compete with each other. Later on, we intend to publish another paper describing the technical issues and technologies involved in the computational supporting framework development.

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Educational visualizations of syntax error recovery

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Abstract— **This work is focused on the syntax error recovery visualization within the compilation process. We have observed that none of the existing tools, which display some views of the compilation, give a solution to this aspect. We present an educational tool called VAST which allows to visualize the different views of the compilation process. Besides, VAST allows to display different syntax error recovery strategies.**

Educational technology; Visualization; Computer science education; Languages

I. Introduction

Language processors or compilers are considered by the students as ones of the most difficult subjects in Computer Science degree. One of the most difficult parts in these subjects is the syntax error recovery.

In the syntax analysis points out the syntax tree (ST) comprehension. The ST concept is basic for syntax analysis and syntax directed translation. The understanding of both topics can be improved using visual representations of the ST. Moreover, the tree representation of the ST is quite similar to student's mental representations of the ST.

Card et al. [7] defined visualization as the "use of computer-based, interactive visual representations of data to amplify cognition". Visualizations, which show the behavior of the internal parsers structures, can be used to make easier the comprehension of the syntax analysis. Nowadays, we have not found any tool which displays the syntax error recovery.

Some syntax error recovery (SER) strategies are difficult to understand for students. Also their implementations in the parser generating tools (e.g. The panic mode error recovery of Yacc): "Proper placement of error tokens in a grammar is a black art…" [13].

Lexical error recovery (LER) is simpler than SER. LER consist in transforming an unmatched string of characters in a valid string using single character modifications (insertion, deletion or modification) or just reporting the error and then restart the lexical analysis process with the next character. However, SER has more implications; sometimes it does not work properly creating new nonexistent syntax errors because the parsing task cannot be interrupted. Furthermore, it is necessary to choose the synchronization point which can force to ignore a part of the input stream or to change it virtually.

The main syntax error recovery strategies are error production, which consists in extending the grammar adding new erroneous productions. Panic error recovery strategy allows the parser to ignore the input stream until find any synchronization token. Finally, the phrase level strategy can make local changes assuming that an unexpected token is correct, for example inserting it into the stack.

Parser generators are commonly used in language processing courses, but the implementation of error recovery methods is far from theory. Obviously, error productions can be used with all parser generators. But, the phrase level is mostly used by LL parser generators, e.g. ANTLR[1]. And the panic mode method is mostly used by LR parser generators, e.g. Yacc[2], Bison[3], and Cup[4]. Even changing the concepts, because the parser developer must specify synchronization points with a special error token, instead of specify synchronization tokens associated with productions.

Visualizing the error recovery process will improve students' understanding of these methods. We have developed VAST [2,4], an educational tool devoted to syntax analysis visualization. VAST has been evaluated in both an educational and observation way [3]. One of the most important features of VAST is its generic approach. It can be used with different parser generators; our students have used it with Cup and ANTLR parser generators. Here we describe how VAST visualizes the different error recovery strategies implemented in both parser generators.

The rest of the article is structured as follows. In the section 2 we describe the related work. In the section 3 we describe the different strategies of error recovery. In the section 4 we explain the visualization of the error recovery with VAST. In the section 5 we describe other characteristics of VAST. Finally, in the section 6 we state our conclusions and future work.

1 http://www.antlr.org/
2 http://dinosaur.compilertools.net/
3 http://www.gnu.org/software/bison/
4 http://www2.cs.tum.edu/projects/cup/

II. RELATED WORK

There exist numerous tools to display some aspects of the compilation process. These tools have been divided according to the use that they are thought for. On one hand there are tools designed to be used mainly with a theatrical aim. However, with this kind of tools the user cannot generate his/her own parsers. Some examples of this type of tools are JFLAP[16], THOTH[8], BURGRAM[9] y SEFALAS[10]. All of them have in common that they animate some aspects of the compilation process such as the table's construction, recognition of the input stream, generation of the syntax tree, etc. On the other hand, there are tools designed to be used with a more practical aim. Some examples of this kind of tools are, ICOMP[6], VisiCLANG[17], APA[12], TREE-VIEWER[19], VCOCO[18], CUPV[11], LISA[14], ANTLRWorks and JACCIE. These tools have two remarkable problems. On one hand they only work with a particular generation tool. On the other hand, they display only certain parts of the compilation process.

There is not any tool that covers the entire parsing algorithm and visualizes all the dimensions –algorithmic behaviour and ST-, therefore it is possible that a teacher has to use more than one, switching between different notations, organizations and visualizations. In this context, the students have to learn how to use more different tools: specification notation, construction process, interpretation of output messages –conflict reports, transitions matrix or items sets-. Furthermore, the teacher has to dedicate time to become familiar with the different environments, and to plan their integration in the course. This makes more difficult their use in educational environments [15].

Focusing on both kinds of tools which have been found, and trying to display the error recovery process, we have realized that except ANTLRworks, none of them visualize this process. In the specific case of ANTLRworks, the visualization of the error recovery process is limited. On one hand, it only allows the visualization for parsers built with the parser generator ANTLR, which also mean for LL(1) parsers. Moreover, it only displays a specific kind of error recovery, the ANTLR one, which consists in inserting the unexpected symbol into the parser's stack. Finally, sometimes the visualization generated can be confusing.

In the Figure 1 it is shown the partial ST built by ANTLRworks when a syntax error occurs. In this case the error is produced because the parser expects a symbol which is not in the input stream, so that ANTLR inserts into the stack all the symbols that it founds although there are not correct. In this case as the error cannot be recovered it reaches the end of input stream, finishing the analysis.

III. SYNTAX ERROR RECOVERY, AN OVERVIEW

The main objective of a parser is to build the ST. But if the input stream is erroneous, then the parser must detect as much existing errors as possible. Therefore, the parser cannot stop the analysis after the first syntax error. Instead, it must move to a correct state and continue with the parsing. This is the main idea of SER.

Typically, four SER methods are taught: phrase level recovery, error productions, panic mode and theoretical [1]. Next we briefly describe each method, note that when we qualify a method as simple or complex we are talking about the student's point of view (understanding).

Phrase level recovery is one of the simplest methods. It tries to transform an incorrect phrase into a correct one by inserting/deleting tokens in/from the input stream. Every state of a parser has a list of expected tokens; they can be used in this recovery method. A common example can be found in most C/C++ compilers, the insertion of the forgotten semicolon at the end of sentences.

Error productions detect specific errors by specifying erroneous grammar productions as they would be correct ones. This recovery is directly specified by the language designer/parser developer. The error treatment is defined in the associated actions of the error production.

Panic mode is more complicated because it simultaneously and explicitly, involves the stack, the input stream and the ST.

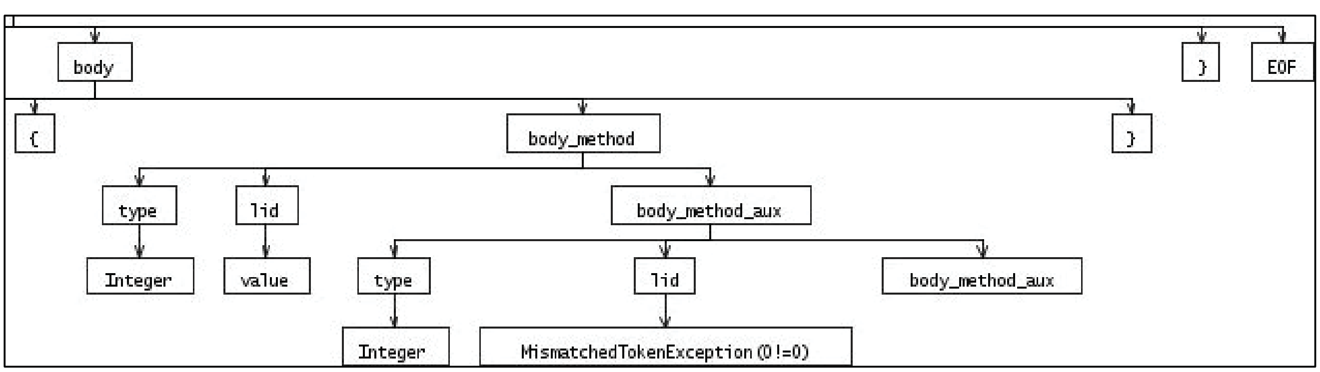


Figure 1. Error recovery visualization in ANTLRworks

This method is based on synchronization points. When an error is detected, the parser discards input tokens until it reaches to a synchronization point. This point is defined by a group of synchronization tokens. To master this method, one must know what are the state of the stack, the input stream and the ST just after the recovery. Besides, it depends on the synchronization token used to recover from the error.

IV. VISUALIZATION OF SYNTAX ERROR RECORY

Visualizing the error recovery process will improve students' understanding of these methods. We have developed VAST [4], an educational tool devoted to syntax analysis visualization. One of the most important features of VAST is its generic approach. It can be used with different parser generators; our students have used it with Cup and ANTLR parser generators. Here we describe how VAST visualizes the different error recovery strategies implemented in both parser generators.

A. *A note about VAST*

VAST has been designed to cope with any parser generation tool independently from the type of the parser generated (LL/LR). In order to get this independence and keep the easy of use as a fundamental requirement, VAST has been divided in two parts: VASTapi and VASTview.

VASTapi is the part encharged of the language processing, its target is to interpret the actions made by the parsers. Finally, it has to create an intermiddle representation, in a xml file, with the content of the ST and the neccesary information which allows it visualization.

VASTview is the part encharged of the visualization. Its function is to interpret and represent visually the content of the xml created by VASTapi.

In order to make this process work correctly, it is necessary to perform an annotation process. This one consists in inserting calls to the methods of VASTapi using semantic actions inside the parser specification. The information needed by VASTapi is the syntactical rule which has been executed. To make this task, the user has to use the method *addProduction("Antecedent", "Consecuent")* of VASTapi. For each syntactical rule is necessary to add the semantic action which communicates, to VASTapi, the rule which has been used.

In the Figure 2 it is shown the user interface of VAST. In the central part it is displayed the ST and in the bottom the different views of the compilation process (input stream, stack, grammar and actions performed). Besides, it includes a global view to make easier the interaction with the ST. Note that in this figure it is used the horizontal distribution. In the Figure 3 it is shown a scheme of how to work with VAST. The process has been divided in design time, which include the annotation process; execution time, when the parser processes an input stream and as a result of the execution of the VASTapi methods, it is built an intermeddle representation in xml; and finally, visualization time, where VASTview interprets the content of the xml file.

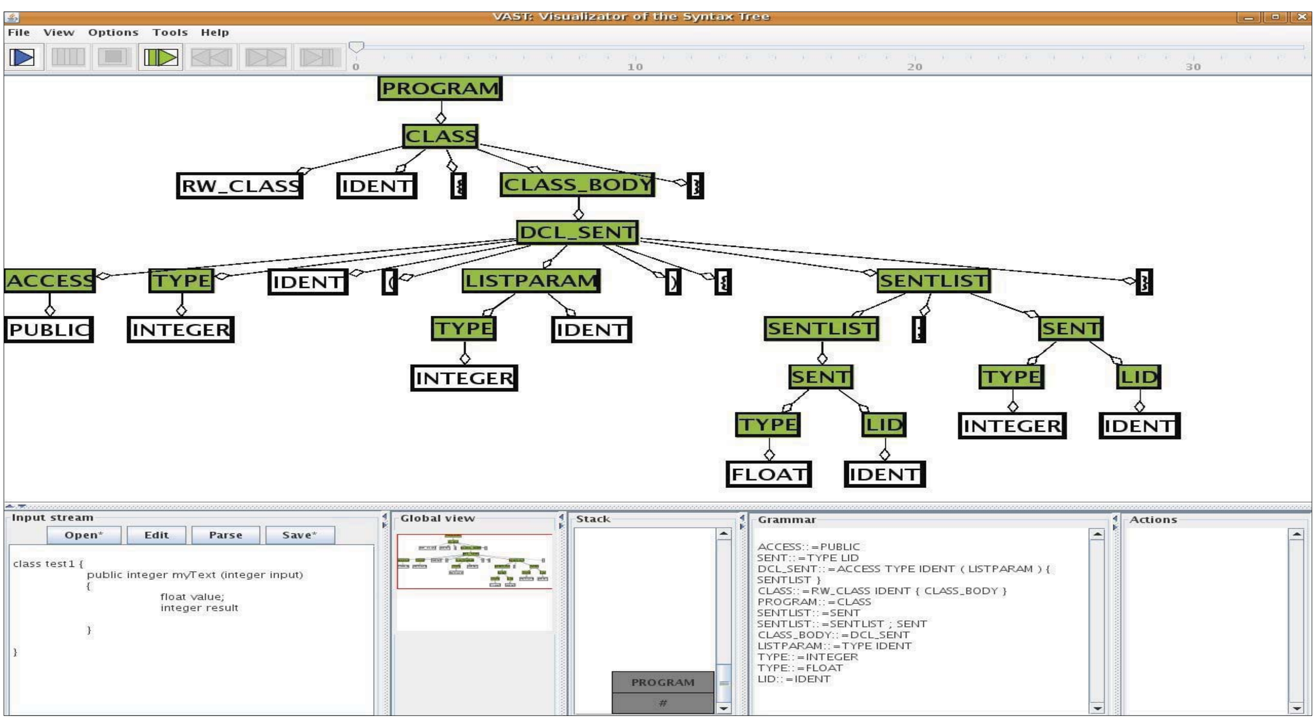


Figure 2. User interface of VAST

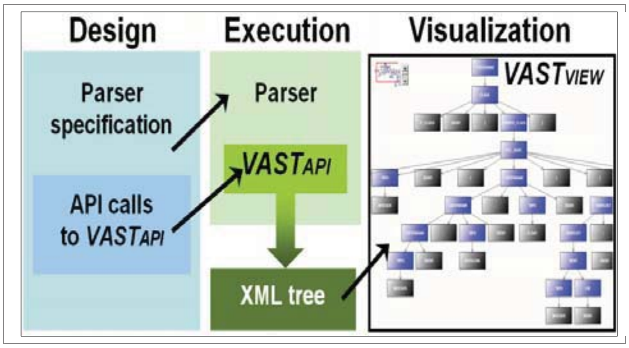


Figure 3. Working with VAST

B. *Visualization of the phrase leve errorl recovery method*

This method is based on token insertion/deletion in/from the input stream. The ANTLR parser generator implements this method by inserting expected tokens. ANTLR allows the parser developer to overload the syntax error recovery method *displayRecognitionError.* We have inserted code that identifies the inserted tokens in the ST.

The main effect of this method is that the terminal nodes of ST (the leaves of the tree) don't correspond to those present in the input stream.

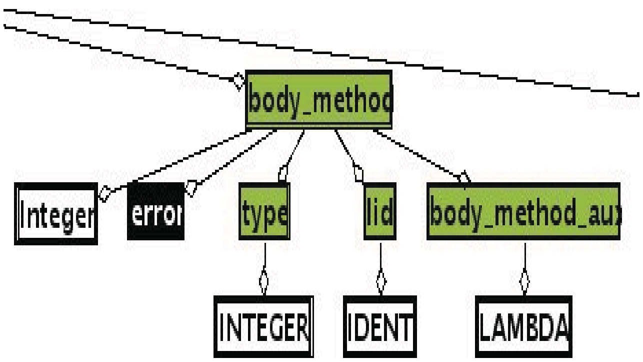


Figure 4. Phrase level recovery with VAST

With VAST we highlight the existing tokens of the ST that have been inserted by the phrase level recovery method.

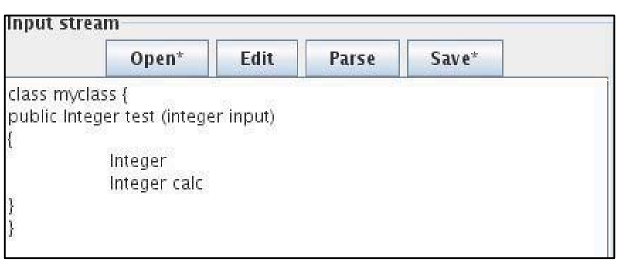


Figure 5. Input stream for LL recovery

In the Figure 4 it is shown an example of an erroneous input stream for a parser generated with ANTLR. As we can see in the input stream in the Figure 5, there is an error in the identifier declaration, so it produces a syntax error. Visualizations can help to understand how this method of error recovery works. When a syntax error occurs, the symbol is shifted into the stack and the analysis continues. In the Figure 6 it is shown the grammar used in the example of the Figure 4.

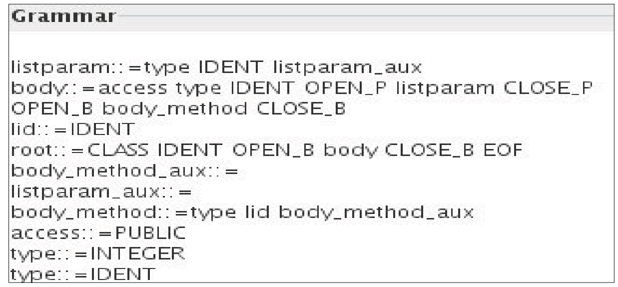


Figure 6. Grammar for LL parsing

C. *Visualization of error productions*

Taking into account that sometimes the error recovery methods implemented in the generation tools are very generic, using error productions allows to perform a more specific error recovery.

In order to make VAST recognize the error productions, it is necessary to communicate it, which productions are used for this error recovery strategy. To obtain this functionality it has been necessary to add a new method called *addErrorProduction("antecedent", "consecuent")* to VASTapi. As we can see, the information communicated to VAST is exactly the same in both cases, in normal productions and in error ones.

VASTview displays an error production highlighting the whole production in a different colour. As result, the user can distinguish that a specific error recovery has been performed.

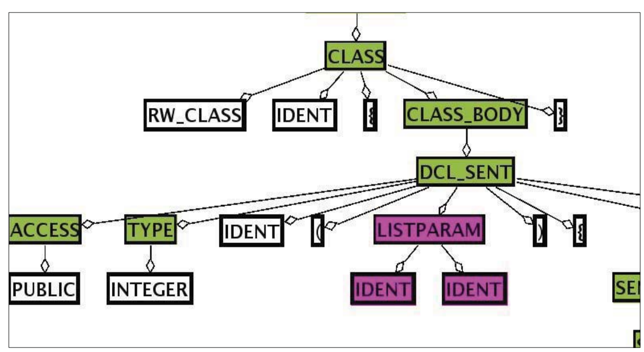


Figure 7. Visualization of error production

In the Figure 7 it is shown an example of error recovery using the error production method. In this case the parser recovers from a specific error produced by an erroneous input stream in the parameters declaration of a method. In the Figure 8 it is shown the input stream using for this example. We can see an error in the parameters declaration of the method *myText.* In the Figure 9 it is shown a fragment of the annotation of the Cup specification to implement this behaviour using error productions. Note that we are using an error strategy not implemented by the generation tools. However, VAST can distinguish this kind of productions, so the visualization adopts the correct aspect.

Figure 8. Input stream for error production recovery

D. *Visualization of panic mode method*

Normally, the panic error recovery is implemented in the generation tools using a special symbol, usually called "error" symbol. This recovery method allows to define easily the synchronization points, however, sometimes it can be extremmely complex to understand how the error recovery strategy works[1].

```
LISTPARAM ::= LISTPARAM COMA TIPO IDENT
| IDENT IDENT
 {:parser.inter.addErrorProduction("LISTPARAM", "IDENT IDENT");:};
```

Figure 9. Annotation for error production recovery

In the specific case of the Cup generator, the panic error recovery is implemented using the Terminal symbol "error". When the parser detects an error in the input stream, it commutes to an internal error stage, inserting into the stack the "error" symbol. To extract this one from the stack it is necessary to find a production which allows to shift the error. If the error can be shifted, then the parser has recovered correctly and the analysis continues. However, if the parser reaches to the grammar axiom and the error has not been shifted, it has not recovered from the error and the analysis will conclude.

To display correctly this process in VAST, it was necessary to implement new functionalities in VASTapi for ascendant parsers. There exist two problems when trying to visualize this process. On one hand, when the parser enters in the error mode, it does not perform any reduction, so that VASTapi does not receive any information of the task done by the parser. On the other hand, as the parser is in an error mode, it does not communicate the ignored symbols to VASTapi. Due to these problems and to obtain these information, it was necessary to modified VASTapi.

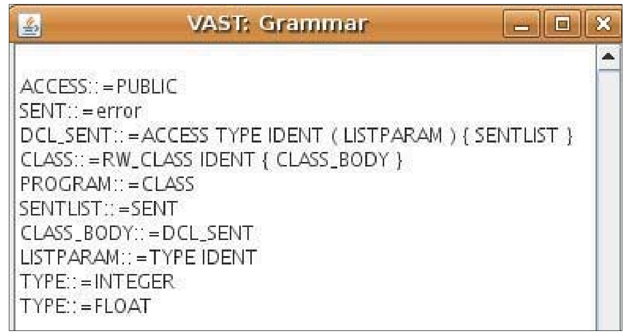


Figure 10. Grammar used for panic error recovery

Instead of solving these problems independently, we have chosen a global solution, which allows to solve both of them. When the parser enters in the error mode, it calls to the *syntax_error* method, which has been overload to communicate to VASTapi that the parser is in the error mode. Besides, in this context, although the parser is in the error mode, it continues asking for symbols to the lexer using the *scan* method.

When VASTapi receives the symbols from the lexer, it marks them indicating their mode (normal or error). Finally, when the error production is performed and the "error" symbol detected, VAST has all the necessary information. On one hand there are the subtrees processed. On the other hand it is the ignored input stream. With this information VAST can create the visualization of this error recovery method.

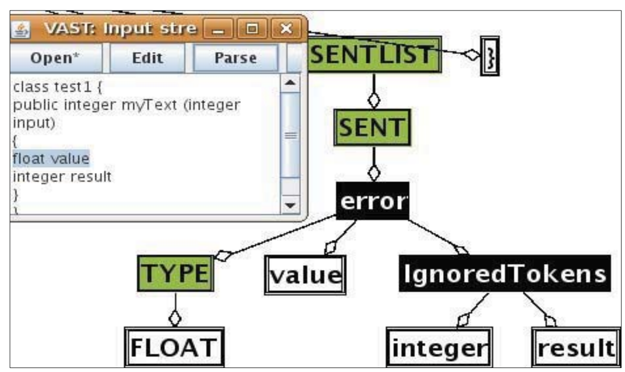


Figure 11. Visualization of the panic error recovery with 1 error

To this end, firstly it is necessary to obtain the synchronization symbol. This one shows the point in which the parser continues the analysis without ignoring the input stream. We obtain this symbol acceding to the last one received when an error production is applied. Secondly, to obtain the ignored symbols it is necessary to access to the received symbols since the parser commuted to the error mode until it received the synchronization symbol. With this information VAST builds a subtree, which root node is the error symbol. The sons of this node are the subtrees processed correctly just before the error occurred and an additional node with the ignored symbols

("IgnoredTokens" node), which contains each one of the ignored symbols.

In the Figure 11 it is shown an example of the panic error recovery. In this case there exists only an error in the input stream, produced because the symbol";" is not after the identifier "*value*". The error recovery implemented used the symbols ";" y "}" as synchronization symbols, so that the parser ignores the input stream until it finds one of those symbols. In this example the parser ignores the "*integer*" and "*result*" symbols. When the parser reads the symbol "}", it recovers from the error and continues the analysis.

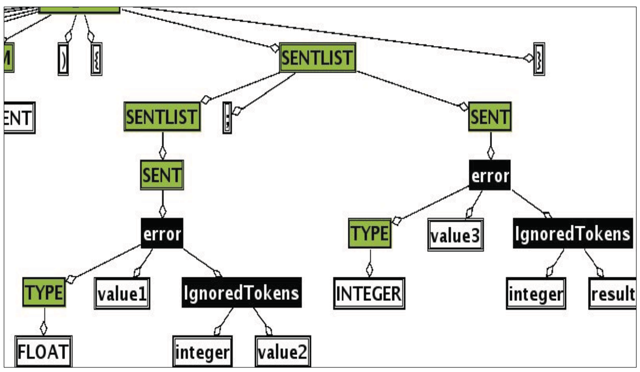


Figure 12. Visualization of the panic error recovery with 2 errors

In the Figure 12 it is shown an example of panic error recovery in which the parser recovers from two errors in the input stream, both produced because there is not ";". As in the previous example, the parser implemented uses the ";" and "}" as synchronization symbols. The first error is produced because after the symbol "value1" it is expected the ";" symbol. However, the parser reads from the input stream the "integer" symbol, so that it enters in the error mode, from which it exits only when reads the ";" symbol. In this case the ignored symbols from the input stream are "integer" and "value2". The second error is produced because as in the first case, there is not ";" symbol. In this case the parser ignores the "integer" and "result" symbols from the input stream. In the Figure 13 it is shown the input stream used to generate the tree of the Figure 12.

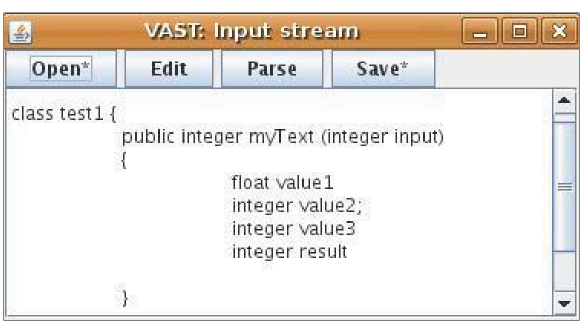


Figure 13. Input stream for panic error recovery with 2 errors

In the Figure 14 it is shown an example in which there are two consecutive errors. In this case as there is not synchronization symbol between both errors, the parser ignores more symbols from the input stream. In the Figure 15 it is shown the input stream used to generate the visualization of the Figure 14.

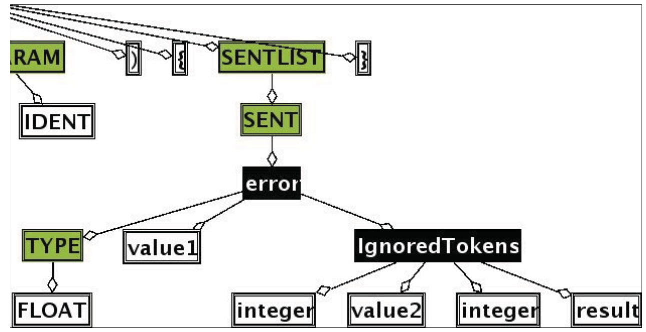


Figure 14. Visualization of panic error recovery with 2 errors consecutive

V. OTHER CHARACTERISTICS OF VAST

Visual representations are not effective educational resources by default, they must be carefully designed. VAST has passed a number of evaluations. As a consequence, we have designed VAST to provide a number of useful features.

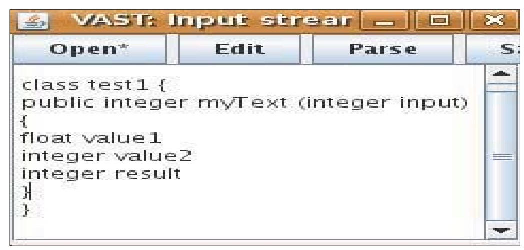


Figure 15. Input stream for error panic recovery with 2 errors consecutive

Apart from inserting additional functionality in VASTapi to interpret the error recovery, we have modified VASTview to handle new functions. It has been improved those characteristic which allow to distribute VAST wider and easier. To this, the user interface has been internationalized into Spanish and English. Besides, we have worked in the platform independence, allowing to work with VAST in Windows, Linux and Mac OS systems. Moreover it has been performed some improvements to work easily with the tool and also to display some specific aspects of the error recovery process that cannot be treated by VASTapi.

A. Visualization of the ST

The graphical representation which has been chosen to visualize the ST is the tree structure resulting of the processing of the input stream. In previous versions of VAST, it can be distinguished three types of nodes: terminal nodes (T), non terminal nodes (NT) and error nodes (EN).

The T nodes are the leaves of the tree, the NT are the internal nodes of the ST and the EN represent the synchronization points in which the parser can recover from an syntactical error. The last one allows to determine the exact place where it is recovered (if possible) a syntactical error. Furthermore, they allow to guess the amount of recognized elements, so the elements recognized before an error occurs will be sons of the corresponding error node.

Due to the changes performed to improve the visualization of the error recovery in panic mode, it has been necessary to create an additional type of nodes, ignored nodes (IN). This kind of nodes has only sense when it is implemented a panic error recovery strategy. When the parser detects an error, it ignores the input stream until it finds a synchronization symbol. The function of the IN is to group the ignored symbols until a syntactical error is recovered. In the graphical representation they appear as sons of the EN, containing all the T ignored.

B. Reproduction of the construction of the ST

The animation of the construction process of the ST is performed using different intermeddle stages generated and ordered by VASTapi. The animation of this process helps the students to understand how the input stream is processed using shifts and reductions.

To reproduce an animation, VASTview has a VCR controls and a slide bar which allows to reach easily to a specific point of the reproduction. During the construction process the ST change its shape, area and content. Due to this behaviour the interface could adapt to each stage using a “best-fit” policy, which would change the location of the nodes of the tree and consequently affect the user. According to this, we have decided to keep the location of the nodes of the tree as the construction process of the ST is reproduced.

The reproduction process is synchronized with all the views offered in VAST, so that when the state of the ST changes all of the views have to act consequently.

In the Figure 16 it is shown an example of the reproduction process of the construction of the ST. In this case the parser is descendant, so as VAST constructs the ST the current node is remarked. In this figure we can see two intermeddle stages of the reproduction.

C. Different distributions

Probably the ST generated by the parsers designed by the students are huge and without any specific structure (symmetric, width and height). For this reason, VASTview has an user interface which make easier the visualization and interaction of the ST.

The interface of VASTview offers three different distributions: horizontal, vertical and float. The horizontal and vertical distributions are used for horizontal and vertical ST respectively. In the case that a ST cannot be classified in any of these types, VASTview offers the float distribution in which the user can change the position of the different views.

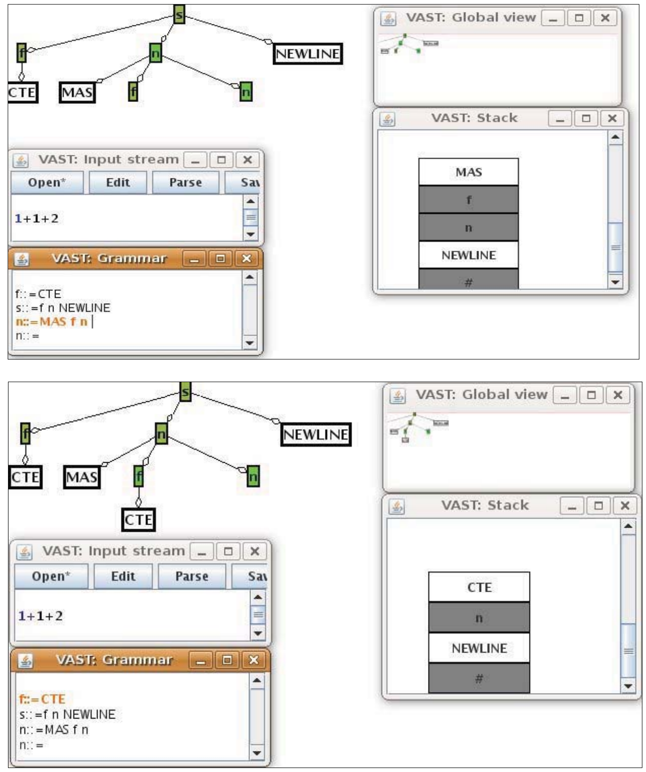


Figure 16. Reproduction of the construction process for LL parser

Independently of the distribution used, the interface of VASTview has a global and detail view of the ST, all together with the zoom and aggregation functionalities. The global and detail view allow the user to manipulate easily the ST. The global view indicates the visible part of the ST in the detail view. The functionalities of the global view give the students the opportunity of examining the ST with zoom, and aggregation, keeping always the synchronization with the global view.

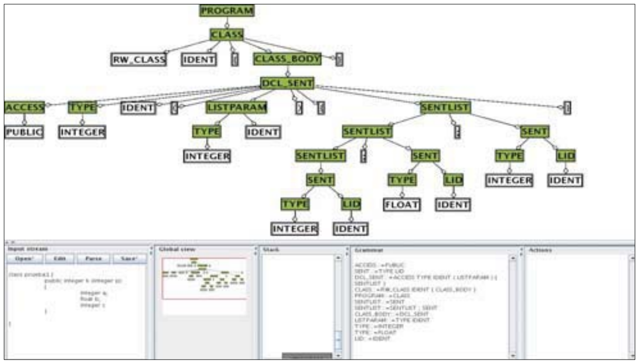
The aggregation allows the user to hide those parts of the ST which are not interesting. In this case, when a node is resumed, we used a “best-fit” policy to redistribute the ST.

In the Figure 17 it is shown the different distribution of the VAST interface. Figures 17a, 17b and 17c show the horizontal, vertical and float distribution of the user interface respectively.

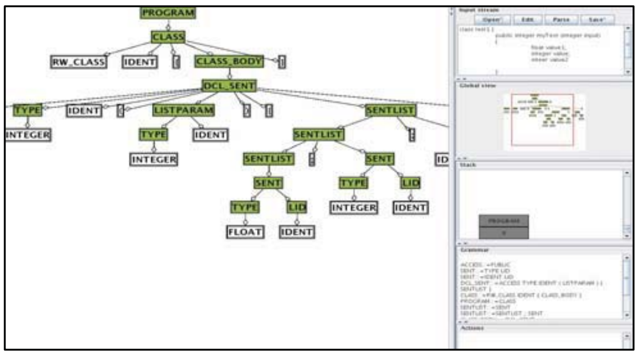
D. Views of the compilation process

Apart from displaying the ST, VASTview visualizes the input stream, the stack of the parser, the used grammar and textual explications of the performed actions. Each of these views have a different aim, however, all of them are really important when the construction process of the ST is animated.

In case of the input stream, it is remarked when the construction process is reproduced. When in the parser is



(a)



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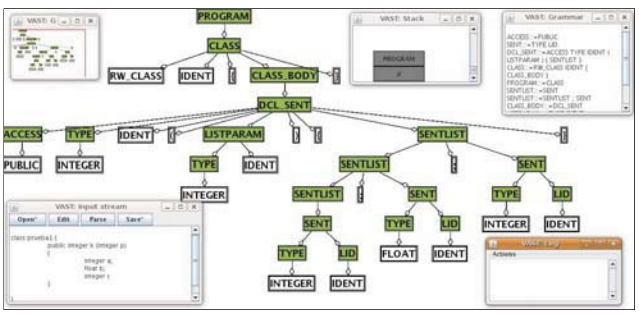

(c)

Figure 17. VAST interface distributions

implemented a method of error recovery, the input stream can distinguishes between the process symbols and the ignore ones. Besides, when the ST is displayed in a static way, if a T node is selected, then in the input stream is remarked the part which corresponds with that node.

The stack view simulates the content of the stack of the parser. It is compatible with both LL/LR parsers and it is really important in the error recovery process, so it is possible to make predictions about the recovery point just observing the content of the stack and the grammar. This view allows to display a stack history, which allow the user to display the different stages of the stack during the analysis.

The visualization of the grammar allows to indicate which syntactical rule has been used in a reduction/derivation. In this case it is necessary to distinguish between the grammar of the specification and the grammar used. The grammar of the specification refers to the set of rules that implements a parser. However, the grammar used is a subset of the previous one, so it is the part of the specification grammar used to process a specific input stream. According to the way of work of VASTapi, it is easier to get the used grammar. So that, when it is displayed the set of rules, it is important to have into account that it refers to the used grammar.

The textual explication was a characteristic asked by the students during the evaluation sessions of VAST. In this case, it has been added the explications of the actions performed during the construction of the ST, including the error recovery process.

Finally, it has been improved the way of showing the views of the VASTview. In this version is possible to hide or change the workspace of each different view. This solution has been necessary to work with low resolution screens.

E. *Importing parsers*

According to the results of the usability evaluation of VAST [5], it was necessary to implement a global integration which consists of two functionality integrations.

The first integration allows to anote a syntactical specification, generate and compile it. The second one allows to execute a parser and visualize the result of this execution.

As result of the implementation of VAST, it has been developed a first approximation of the importation of parsers. In the case of the second integration it has been developed in a generic way. However, the first integration has been implemented just for the ANTLR specification. This limitation does not involve VAST, but the necessity of creating metaparsers which can annote automatically the specification including the VASTapi calls.

VI. CONCLUSIONS

In this work, we has presented the educational tool VAST, which allows to visualize the ST and the different views of the compiling process. The main characteristics of VAST are the independence from the generation tool and the easy of use.

Specifically, within the visualization of the ST, we have studied the existing tools and realized that the existing tools to display the compilation process, give a partial or/and particular solution. On one hand, these tools are particular because they only allow to display the parser created for a concrete generation tool. On the other hand, they give a partial solution because they do not show all the views of the compilation process.

In this context when we focus on the syntax error recovery visualization, we observe that none of these tools give a solution for it. We has found only one tool, ANTLRworks, which give an approximation of the syntax error recovery visualization. However, as in the other cases, the solution implemented is particular and partial. Taking into account that SER is one of the most difficult points in the language processor courses, and the pedagogical effect that visualizations have in education, we have decided to use the visualizations technologies to improve the comprehension process of the syntax error recovery.

We have added new functionalities to VAST, in order to display the syntax error recovery. We have detailed the different characteristics of each error recovery strategy. Afterwards, we have explained how they are implemented in VAST. As a result VAST allows the visualization of the insertion error recovery, error productions and panic mode error recovery.

Furthermore, in this work we include the functionality of importing parsers specifications. This one allows to display any parser in a very easy way.

The work with VAST has not finished yet. As future works we plan different evaluations of the new functionalities. Moreover, we will work on the exporting of animations to be used in different contexts (e.g Powerpoint). Finally, it will be necessary to improve the importation of parsers, so this version allows only to import automatically ANTLR specifications.

VII. ACKNOWLEDGEMENTS

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Session 05E Universia Special Session: International Engineering Cooperation

Tokyo Tech Graduate Program Allied with Thailand: TAIST (Thailand Advance Institute of Science and Technology) - Tokyo Tech

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Engineering in Latin America: A view at the Higher Education Level

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Innovative Practices for Learning Human-Computer Interaction by Engineering Learners

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Tokyo Tech Graduate Program Allied with Thailand

TAIST (Thailand Advance Institute of Science and Technology) - Tokyo Tech

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Abstract—**Tokyo Institute of Technology has been active in academic collaboration with Asian countries, and we opened our overseas offices in Bangkok, Manila, and Beijing, in 2002, 2005, and 2006, respectively. International distance education has also been conducted since 2002. Backed up with those experiences, in 2007 we started a new graduate program allied with National Science and Technology Development Agency (NSTDA) and Thai universities. The program is called Thailand Advance Institute of Science and Technology (TAIST) - Tokyo Tech. TAIST will serve as a virtual institution and focal point. NSTDA provides researchers to act as adjunct professors, research projects and scholarships for graduate students. Thai universities provide an academic framework, academic staff to oversee and guide students and degrees for the successful candidates. Currently two master programs are running; Automotive Engineering (AE) and Information and Communication Technology for Embedded Systems (ICTES). Tokyo Tech is responsible for most of its coursework. To get rid of long travel between Tokyo and Bangkok (separated by 4,600km), distance education is effectively utilized. In the ICTES program, 7 lecture courses out of 18 are entirely taught from Tokyo, and some others combine distance education. All the course materials are uploaded on the e-learning site, where lecture videos are also available for some courses. TAIST-Tokyo Tech is expected to initiate the start of a positive spiral of human resource development system in Asian region. TAIST-Tokyo Tech aims to harmonize advanced technology with the environment and to realize research and human resource development for global sustainable development. Operations of this graduate program and distance education activities are introduced.**

Keywords- Allied graduate school; distance education; international collaboration

I. INTRODUCTION

Information and communication technology can suitably be used to overcome not only physical distance but also mental distance between learners and teachers as well as among learners. Tokyo Institute of Technology (Tokyo Tech) installed Academic Network for Distance Education by Satellite (ANDES) system in 1996, and utilized it for various kinds of distance education programs; university - high school collaboration, lecture exchange with Hitotsubashi University, lecture distribution to workplace engineers, and international distance education. In some parts on the globe, internet is not yet developed well, and satellite communication is important. On the other hand, in many other places (especially in big cities) broad-band internet connection is well established and even high-definition video communication is possible. Internet environment is considered to gradually develop and distance education will become easier to conduct from the viewpoint of communication channel.

II. TOKYO INSTITUTE OF TECHNOLOGY

Tokyo Tech is ranked No. 55 in the Times Higher Education-QS World University Rankings 2009 (No. 19 in engineering and information technology).

Among about 10,000 graduate and undergraduate students, there are 1,100 foreign students. This ratio of foreign students is one of the highest in Japanese universities.

Tokyo Tech started International Graduate Program in 1993, in which students can take entrance examinations and lectures in English. Students are enrolled in October, unlike regular enrollment in April. Currently, a choice of seven curricular programs in which students can obtain a master's or doctoral degrees in English is provided in the International Graduate Program. More than 100 courses are currently taught in English. The program now makes it possible for qualified students with little or no knowledge of Japanese language to pursue a full degree-course of advanced study in this country. The provision of such a program not only eliminates the previous language requirement but also, thereby, significantly shortens the period of study. It can thus be said that the program provides qualified overseas students with another option for admission to graduate schools. Since lectures and seminars are given in English, it is no longer essential to master the Japanese language. However, since Japanese is the language of daily life, students in the program are encouraged to attend a few Japanese classes per week on a regular basis for further enrichment.

Tokyo Tech Open Course Ware (Tokyo Tech OCW) [1] is a platform maintained by Tokyo Tech for providing free access to course materials for users around the world aiming at releasing the Tokyo Tech's high-level educational resources on science and technology as the world's public property. Tokyo Tech OCW is one of the core material of the web-based electronic knowledge system. Starting in May 2005, Tokyo Tech OCW covers all of 1,910 undergraduate and 1,581 graduate courses, for which course outlines are shown. Lecture materials are shown for more than 551 courses at this moment, and we will cover almost all the courses in the future. This number of 551 courses is more than half of the total lecture materials released by Japanese OCW Consortium consisting of major Japanese universities in cooperation with Massachusetts Institute of Technology. Tokyo Tech OCW pages get more than 6,000 hits per day, which is about 20% of the whole accesses to Tokyo Tech web pages.

III. DISTANCE EDUCATION AT TOKYO TECH

The Center for Research and Development of Educational Technology (CRADLE), established in 1973, set up the ANDES system in 1996, for the use in lecture deliveries via commercial communication satellite. The ANDES system has been used for lecture exchange with Hitotsubashi University, famous national university in social science, open lecture delivery to workplace engineers, and high-School university collaboration in which undergraduate lecture courses are transmitted to high-school students all over in Japan who are interested in science and technology. Since 2002 some of the courses taught in English in the International Graduate Program are transmitted to Thailand using ANDES system [2]. We use 3Mbps or 6Mbps MPEG2-DVB for video transmission. The lectures were received by NSTDA, Asian Institute of Technology (AIT), and King Mongkut's Institute of Technology Ladkrabang (KMITL). The courses to be transmitted are chosen by the request from the Thai side and willingness of lecturers. All the courses had been taught in English and not much load is added to the lecturers. Lecturers are requested to put their lecture notes on the Tokyo Tech OCW (or send them to the students) in advance of the lecture. Since 2006 we use a Japan-Thai land link of Japan Gigabit Network 2 (JGN2, and it is JGN2plus since 2008), an open testbed network environment for research and development, which is operated by National Institute of Information and Communications Technology (NICT) [3]. JGN2 is an ultra-high-speed testbed networks for research and development collaboration among industry, academia, and the government with the aim of promoting a broad spectrum of research and development projects, ranging from fundamental core research and development to advanced experimental testing, in areas including the advancement of network-related technologies for the next generation and diverse range of network application technologies. We mainly use H.323 audio-visual communication sessions with about 500 kbps, but we are testing the use of high-definition (1920x1080) video transmission [4].

To manage the international distance education and research collaboration, Tokyo Tech Office (Thailand) was established in 2002 in the NSTDA building in the Thailand Science Park (TSP). In 2005 Tokyo Tech Office (Philippines) opened at De La Salle University, Manila, and Tokyo Tech Office (China) opened at Tsinghua University in Beijing in 2006. Those offices act as communication hubs for people in those areas. Through these offices remote students are taken care of. The Offices also handle research partnerships and information about studying at Tokyo Tech, and offer guidance for academic-industrial collaboration.

IV. TAIST TOKYO TECH

Based on those experiences and MOU with NSTDA, we established a new graduate program named TAIST. TAIST is based on the idea of collaboration among Tokyo Tech, NSTDA and partner universities to develop the human resources. TAIST will serve as a virtual institution and focal point. NSTDA provides researchers to act as adjunct professors, research projects and scholarships for graduate students. Tokyo Tech provides world class background, expertise and experience, academic instruction and research advice. Thai universities provide academic frame work, academic staff to oversee and guide students, and degrees for the successful candidates. The viability of the idea is nicely demonstrated by the creation of TAIST Tokyo Tech.

The main objective of TAIST Tokyo Tech is to establish an institution for human resource development to foster and support world-class researchers and high-level engineers through a combination of advising from Tokyo Tech professors, excellent facilities and research staff in NSTDA, and established resources of Thai universities. The participating Thai universities are KMITL, Sirindhorn International Institute of Technology (SIIT), Kasetsart University (KU), and King Mongkut’s University of Technology Thonburi (KMUTT).

NSTDA is an agency under the Ministry of Science and Technology and supports research in science and technology and their application in Thai economy. It promotes innovation and research activities in Thailand. Its mission is research and development to strengthen Thailand's sustainable competitiveness, complemented by technology transfer and the development of human resources and science and technology infrastructure, with outcomes that have positive impacts on society and the economy. It is affiliated by 4 research centers;

- National Center for Genetic Engineering and Biotechnology (BIOTEC)
- National Metal and Materials Technology Center (MTEC)
- National Nanotechnology Center (NANOTEC)
- National Electronics and Computer Technology Center (NECTEC)

NSTDA and those 4 research centers are located in the TSP about 40km north of central Bangkok. The TSP is the country's leading integrated R&D hub which came into operation in 2002. The TSP is also located close to three of Thailand's leading universities; AIT, SIIT, and Thammasat University. Tokyo Tech Office (Thailand) is a tenant of TSP.

NSTDA prepares TAIST classrooms in the TSP with distance education equipment and internet infrastructure. It also lends a notebook PC to each of TAIST students.

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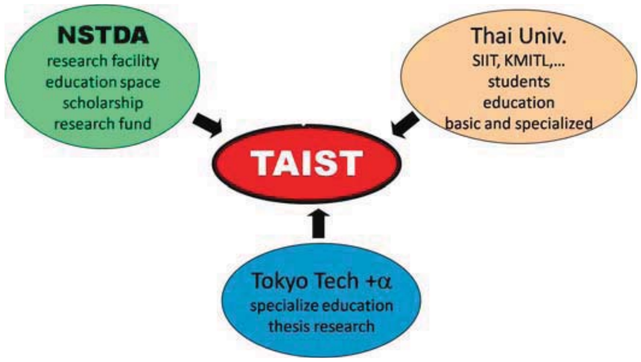

Figure 1. Concept of TAIST Tokyo Tech

The TAIST Tokyo Tech project aim to attain world top level performance by mobilization of whole institutional resources based on long history of education and research of participating institutions. Tokyo Tech and TAIST Tokyo Tech share the same philosophy of education and research - "human resource development by promoting cutting-edge research activities".

It is expected that TAIST Tokyo Tech will initiate the start of a positive spiral of human resource development system in Asian region. TAIST Tokyo Tech aims to harmonize advanced technology with the environment and to realize research and human resource development for global sustainable development. Looking back at the history of modernization through industrial development, factors such as global warming, unusual weather and the pollution of air, water and soil indicate that there is a real risk of serious destruction of nature and life in the near future. It is urgent for us to recognize this paradigm shift in science and technology and concentrate our effort and intelligence on technologies which are in harmony with the environment. In Thailand, development and industrialization have been so drastic, compared with developed countries, that problems derived from these factors are much more serious as they become obvious. In light of such a situation, expanding research and education to harmonize advanced technology with the environment effectively and efficiently will be quite necessary and the outcome of such effort will be valuable for Thailand, as well as other countries of the world.

All first year students receive full scholarships for tuitions and fees. In the second year, researches for dissertations will be carried out mainly in NSTDA various laboratories with NSTDA researchers acting as supervisors or co- supervisors. The second year students are expected to receive scholarships for tuitions and fees from research projects of their supervisors. Professors from Tokyo Tech will actively participate in the educational process of the students throughout each program. After a successful completion of both course work and thesis, the students receive degrees from the host universities and certificates from Tokyo Tech. These programs are:

1. Master's Degree Program in Automotive Engineering. The program started accepting the first group of students in the Academic Year 2007. The host universities are KMITL and KMUTT, and the host institute at NSTDA is MTEC.

2. Master's Degree Program in Information and Communication Technology for Embedded Systems (ICTES). The program started accepting students in the Academic Year 2008. The host universities are SIIT and KU, and the host institute at NSTDA is NECTEC.

3. Master's Degree Program in Environmental Engineering. The program is expected to start in the Academic Year 2010.

4. Master's Degree Program in Biotechnology is now under discussion for its start.

Each program accepts 30 students every year. TAIST students are not restricted to Thais. In fact there are students from neighboring countries in AE program, and we hope more students will come to TAIST programs from various countries.

V. TAIST ICTES PROGRAM

The goal of the TAIST program in ICTES is to prepare students with comprehensive understanding of the hardware and software technologies in ICTES, with in-depth knowledge of embedded systems in VLSI designs and embedded software development, as well as broad knowledge of their applications in communications, networking, signal processing, human interface, artificial intelligence, etc. Students also experience actual development of embedded systems using the state-of-the-art Computer Aided Design (CAD) tools for both hardware VLSI (Very Large Scale Integration) and software in "Embedded Systems Design Exercise Class". Here, students work in teams to also learn about project management, product planning and marketing aspects of the embedded systems development. Master of Engineering. program in ICTES welcomes full-time students as well as part-time students from the industry, both of which will greatly benefit from the unique learning environment which this program is designed to provide. Furthermore, the graduates of this program can further pursue a doctoral study at Thai universities or at Tokyo Tech. ICT (Information and Communication Technology) is the fastest growing sector in the economy with a 70% increase in growth rate projected between 2002 and 2012. However, there is an enormous shortage of ICTES engineers, especially in the area of embedded systems, and this trend will continue to grow with the coming of the "ubiquitous society" in a global scale. The Master of Engineering program in Information and Communication Technology, therefore, has been established to offer an outstanding and state-of-the-art education in both theoretical and practical areas in ICTES with a strong focus on embedded systems. It is expected that all Thai graduates of the Master of Engineering Program in ICTES acquire the necessary skills to be the leaders in Thailand's electronics industry, and also to be highly competitive in the fast-growing global embedded systems market.

TAIST ICTES program has the courses shown in Tables 1 and 2.

TABLE I. REQUIRED COURSES

Computational Mathematics Set theory; Relations; Formal proof methods; Finite automata; Regular expressions; Context-free grammar; Pushdown automata; First order logic; Theories related to counting, graphs and networks; Interplay between continuous models and their solution via discrete processes; Vector spaces, basis, dimension, eigenvalue problems, diagonalization, inner products, unitary matrices; Introduction to applied statistics and its application to intelligent systems; Introduction to supervised statistical learning including discrimination methods
Software for Embedded Systems Software programming; Embedded operating systems and middle-wares; Verification and testing for Embedded Systems; Software issues in the design of embedded systems; Microcontroller architectures and peripherals; Compilers and debuggers; Timer and interrupt systems; Interfacing of devices; Software issues in communications and networking.
Hardware for Embedded Systems Basic digital system design; Processor architecture design; Very Large Scale Integration (VLSI) design methodologies; Hardware concepts on microcontroller architectures and peripherals; Device interface; Hardware for communications and networking
Software Design Exercise for Embedded Systems Hardware and software development tools; software project management techniques and tools; Embedded operating systems; Software development project: requirement analysis, software detailed and test case design, software coding and testing, software documentation; Project planning; System specification design; Software coding; Software implementation and verification on Field-Programmable Gate Array (FPGA) prototype board.
Hardware Design Exercise for Embedded Systems Hardware development tools; Hardware Description Language (HDL); Field-Programmable Gate Array (FPGA) design flow: input and output pin assignment, synchronous and asynchronous logic design, logic simulation and optimization, verification of design constraints; Custom hardware development project; Software and Hardware implementation and verification on FPGA prototype board; Practical issues on microcontroller and FPGA.
Research Methods in Information and Communication Technology for Embedded Systems Research principles and methods in information and Communication Technology for embedded systems problem analysis for research topic identification, data collecting for research planning, identification of samples and techniques, research analysis, result explanation and discussion, report writing, presentation and preparation for journal publication.
Seminar in Information and Communication Technology for Embedded Systems Presentation and discussion on current interesting topics in information and Communication Technology for embedded systems at the master degree level.

TABLE II. ELECTIVE COURSES

Communication Information theory; Signal processing; Communication systems; Data and digital communication concepts; Theory and techniques in data communications: transmission, encoding, decoding, error detection, error correction, link control, networking, and standards; Communication hardware and software; Synchronization subsystems; Time-division multiple-access systems; Code-division multiple-access systems.
Signal Processing Digital signal processing theory; Video and audio processing; Discrete-time signals and systems; Linear time-invariant systems; Sampling of continuous-time signals and convolution; Infinite Impulse Response (IIR) and Finite Impulse Response (FIR) filter designs; Discrete Fourier transform; Fast Fourier transform algorithms; Relations between Fourier Transform (FT), Discrete-frequency Fourier Transform (DFFT), Fourier series Discrete-time Fourier Transform (DTFT), and Discrete Fourier Transform (DFT); Speech analysis; Speech recognition; Speech sysnthesis; Vector quantization (VQ) techniques; Hidden Markov model (HMM); Speech and audio coding; Noise reduction; Morphological analysis; Formal language; Parsing; Spoken language human interface; Image transformation and filtering, image segmentation, image object detection, High-efficiency video coding fundamentals, video coding standards, processing requirements, architecture for the DCT, hardware for motion compensation, nonstandard coding techniques, perspective on the "ke-tai"(mobile phone) service, network human interface
Intelligence Processing Human interface; Human information processing; Artificial intelligence; Concept and design of human-machine interface; Trends of human interface design; Graphic user interface, interactive software design; Hardware technology for human interface; Foundations of human visual and auditory systems; Information processing of the perceptual systems; Color vision, Space perception; Auditory and visual scene analysis; Current research and application of artificial intelligence; Artificial intelligence languages; Search techniques; Knowledge representation, reasoning and inference; Machine learning; Expert systems.
Environment and Control Systems Control system theory; Laplace transform; Control system description and block diagrams; Dynamics of typical controlled systems; Development and simplification of transfer functions; Analytic tools for predicting system response and performance; Geographic Information Systems(GIS) for environment control; spatio-temporal database, fusion of embedded systems and distributed intelligent systems, remote-sensing techniques for environment control; Disaster Control Systems; Spatio-temporal GIS for disaster prevention, map-embedded information processing systems for local government,

mitigation of earthquake disaster, tsunami disaster, Car navigation systems; data structure for car-navigation, map-data utilities; Environment control systems, Power management systems and methods
Selected Topics in Information and Communication Technology for Embedded Systems Selected topics in information and Communication Technology for embedded systems at the master degree level. Topics are subject to change each semester.

In addition to taking courses, all the students are required to perform research and write their master theses.

Thesis

- Each student is assigned to a laboratory in NASDA in the second semester.
- In the thesis project (2nd year) the students perform research under the supervision of Thai University staff (*advisors*), NSTDA staff (*co- advisors*) and Tokyo Tech staff (*co- advisors*). Advisors and co-advisors compose a thesis committee.
- The students receive credits for the thesis project.
- The project is conducted at NSTDA laboratories.
- In order to prepare for the thesis project and get an overview of ongoing research, students attend the master seminar and a course on selected topics in embedded systems. After choosing a topic for a thesis project, but before actually starting the research, a student writes a thesis proposal containing a problem statement for the proposed research, positioning of the research with respect to other research, an overview of the literature in the field, and a planning for the project. The proposal should be accepted by the thesis committee before the project can start.

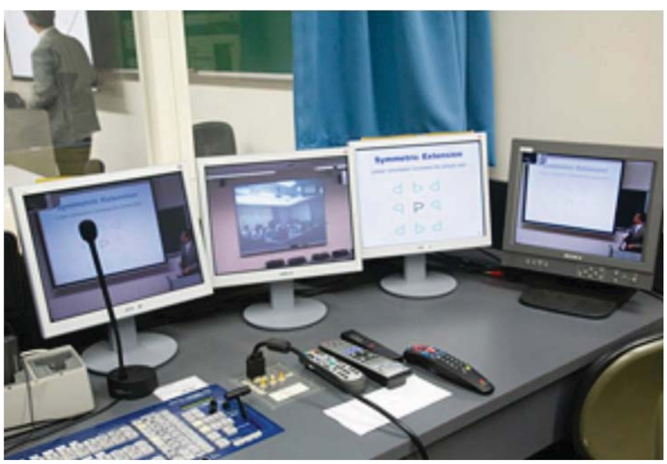

Figure 2. Distance Education Control Room

- The students perform the research according to the plan in the thesis proposal and write theses about the result.
- The project is finished with a defense of the thesis in front of the thesis committee.

V. DISTANCE EDUCATION FOR TAIST ICTES PROGRAM

TAIST ICTES lecture courses are taught by a team of Tokyo Tech professor as a main lecturer and a Thai faculty member as a co-lecturer. Co-lecturers supplement the course taught by main lecturers and undertake exercises. In 2008 among 18 courses 7 were 1-week intensive face-to-face lectures given by Tokyo Tech professors who traveled to Bangkok, 7 courses were completely delivered from Ookayama campus in Tokyo or Suzukakedai campus in Yokohama of Tokyo Tech, and the rest were combination of face-to-face and distance education.

We use H.323 video conference system with about 500kbps. Fig. 2 shows a control room attached to a distance education classroom. There are 4 video cameras and 2 video projectors in this classroom. A lecturer can give a lecture by showing a computer screen or by writing on a blackboard. He can see students in the remote site behind local students (if any) sitting in front of him.

Since most of Tokyo Tech professors are not accustomed in conducting distance education, CRADLE distributed a one-page instruction entitled “Notes on Distance Education”, which had been used in conducting distance education. In addition, we had a training session entitled “How to Conduct TAIST ICTES Distance Education”, which includes operation of communication equipment, usage of tools, and educational methods. A Teaching Assistant (TA) is assigned to each lecture course, and he/ she helps the lecturer by assisting the preparation of lecture materials, connection with the remote site, and controlling the cameras. Lecture materials and other information for students are put on a special TAIST ICTES site named ELITE (E-Learning for Information Technology Education) operated using a hosting service of Tokyo Tech TSUBAME super computer.

Figure 3. Lecture Transmitted from Tokyo

Figure 4. TAIST ICTES Classroom

For some TAIST ICTES courses, lectures are recorded and the videos are put on the ELITE site together with the lecture materials as shown in Fig. 5, so that students can review the courses afterward.

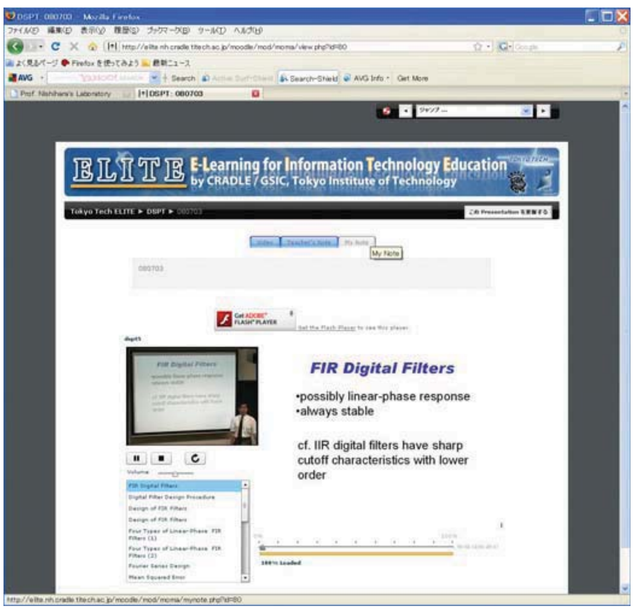

Figure 5. ELITE Site

In the thesis projects, second year students have to make presentations for thesis proposal, progress report, and final defense. We use video conference systems for such occasions.

After finishing the first academic year, we compared the grades of the 26 first-batch students. Except for some students who did not take some elective courses, we compared grades of 7 distance education and 7 face-to-face courses for each of 21 students, and we found no significant differences. This is probably because the number of courses in each style and the total number of courses per student are too small. So we compared the grades of all the students in the lump. The results are shown in Fig. 6, where face-to-face courses have higher grades with 99% significance. As seen in the figure, the course "4.1 Digital Signal Processing Theory" has the lowest score among all the courses, and the course "5.2 Human Information Processing" has the second lowest score. The courses 4.1 and 5.2 are difficult subjects from the lecturer point of view, and the lecturer of 4.1 is probably too strict in grading. If we exclude the course 4.1, there is no significant difference between distance education and face-to-face courses.

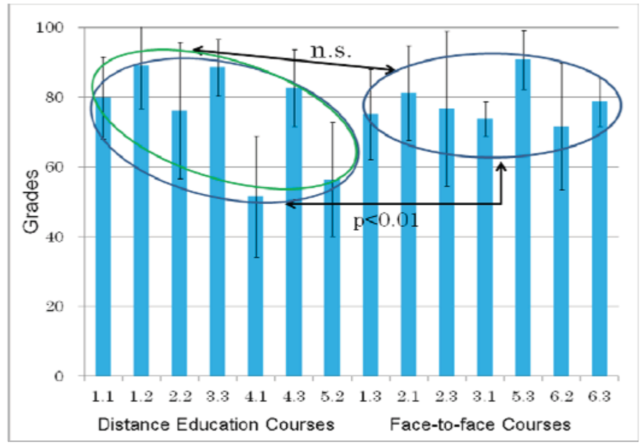

Figure 6. Comparison of Grades

The grades have 99% significant correlations between the following 4 pairs;

- "1.1 Algorithm and Software Design" and "2.2 Processor Architecture Design",
- "1.1 Algorithm and Software Design" and "2.3 VLSI Design Methodology",
- "1.2 Embedded Software Design Techniques" and "2.1 Basic Digital System Design", and
- "1.2 Embedded Software Design Techniques" and "2.3 VLSI Design Methodology".

Those courses cover fundamentals of hardware and software, and so it is considered to be natural that there are correlations among those courses. Other pairs of courses that have correlations with marginal significance are as follows;

- "1.1 Algorithm and Software Design" and "5.2 Human Information Processing",
- "1.1 Algorithm and Software Design" and "2.1 Basic Digital System Design",
- "1.2 Embedded Software Design Techniques" and "2.2 Processor Architecture Design",
- "2.2 Processor Architecture Design" and "1.3 Real Time System Design",
- "2.2 Processor Architecture Design" and "2.1 Basic Digital System Design",
- "2.1 Basic Digital System Design" and "2.3 VLSI Design Methodology", and
- "2.3 VLSI Design Methodology" and "6.2 Environment Control System".

The following one pair;

· “2.2 Processor Architecture Design” (distance education) and “3.1 Information and Coding Theory” (face-to-face education)

has negative correlation coefficient of -0.965 with 95% significance. They are, of course, rather different, but there may be other reasons. Investigation will be continued for the following years.

ELITE site is also used as a student evaluation system using 4 Lickert scale questionnaires. Some of the results are shown in Fig.7. Sense of achievement for distance education is higher than that of face-to-face education with marginal significance. This is probably because students felt more sense of achievement after overcoming the unusual situations of distance education. Other items of questionnaires have no significant differences between distance and face-to-face education. We believe that those facts justify the use of distance education. It is to be noted, however, that those result from much effort of lecturers and co-lecturers.

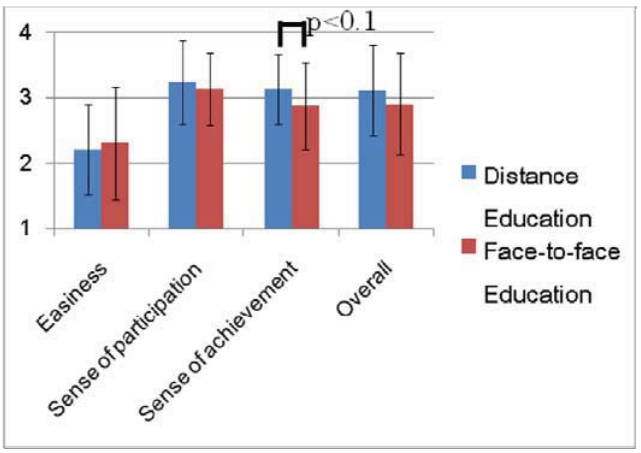

Figure 7. Comparison of Questionnaire Results

For the course “4.1 Digital Signal Processing Theory”, questionnaire results are summarized in Table 3. The results are generally favorable, but improvement is necessary for picture quality, sense of participation, and sense of achievement. The score is not so good for the question to compare the course with face-to-face lecture. It is 2.5, just a median of 1 and 4. So we believe we are doing well.

To improve the picture quality, we are seeking for the use of high-definition video in which lecturer’s facial expressions are easily seen [5], and lecturer can much more clearly see the students. The key for that is whether we can secure enough bandwidth, which is still a big problem because internet is usually a best-effort network.

TABLE III. QUESTIONNAIRE RESULTS

Question	1	Average	4
Interest	uninteresting	3.5	interesting
Easiness	difficult	1.9	easy
Lecturer’s face	Unseen	3.5	seen
Moving picture	Bad	2.9	good
Lecturer’s voice	unclear	3.7	clear
TA’s help	useless	3.8	useful
Exercise format	Bad	3.5	good
Sense of participation	not felt	3.2	felt
Sense of achievement	not felt	3.2	felt
Compared to f2f	Bad	2.5	good
Overall Bad		3.0	Good

VI. CONCLUSIONS

New joint graduate program operated by Tokyo Tech, NSTDA, and Thai universities is introduced, where distance education is well utilized. The roles of co-lecturers are very important to have good educational effects, if not comparable to face-to-face courses. The program has just started, and continuous improvement is necessary in educational systems, technical supports, and collaboration framework. Joint degree system will be much more attractive for many students, and we are studying its feasibility.

ACKNOWLEDGMENT

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Engineering in Latin America: A view at the Higher Education Level

Special Session

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Abstract— **A special session is proposed to present a view of the current status of Engineering Higher Education in LatinAmerica with respect to areas in which UNIVERSIA is promoting.**

Keywords: Engineering, Higher Education

I. Introduction

UNIVERSIA, launched in Spain on 9 July 2000 with a clear vocation of serving the university community in Latin America, is the largest Latin American network of university collaboration. It includes 1,100 universities and colleges in 15 countries. Universia partner universities represent 76 percent of the university group of countries where it operates, with 10.9 million students and 885,000 teachers.

UNIVERSIA tries to act as a promoter of change and innovation to help universities to develop shared projects. Also it creates new opportunities for the university community in order to meet the demand of the business environment and institutional sustainability criteria. Its vision in this way is to be the largest network of Spanish and Portuguese that promotes academic and the university-industry cooperation.

II. Focus Areas

This session will include papers concerning the action lines promoted by UNIVERSIA:

1. Information to support learning and training.
   - Detecting the necessities for corporate training and disseminating the academic knowledge with training resources throughout universities.
   - Disseminating business experience to the university environment.
2. Employment. Practice and career development.
   - Helping universities to increase the employment opportunities of graduates in collaboration with university employment services.
   - Helping companies in the selection process for graduates and internships.
   - Opening to teachers and researchers channels of communication with companies and institutions for business development of research results.
3. Observatory. Center for the future of science and higher education.
   - Building physical and virtual spaces for debate and discussion on trends in higher education involving all stakeholders (companies, institutions, universities, government, etc).
   - Helping the academic community in the process of transition to the new educational scenario.
4. Social Networks.
   - Creating platforms for leisure participation on issues of interest to academics (virtual environments, social environments, chats, blogs, contests, etc.).
   - Organizing events that promote responsible and participative entertainment (music, sports, debates, etc.).

Innovative Practices for Learning Human-Computer Interaction by Engineering Learners

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Abstract—**This paper presents an innovative experience with teaching and learning Human-Computer Interaction in the field of Computer Engineering in the Faculty of Physical Sciences and Mathematics at the Universidad de Chile. This is a pioneering course in Latin America, and has been offered every year for the past 20 years without interruption. The content of the course is constantly renewed and updated. As a result, students have been able to learn of a wide range of aspects regarding Human-Computer Interaction that must be taken into consideration when designing any kind of software or device for human use. At the same time, students recognize that the issues and methodologies taught in the course are not only useful for their training as engineers, but are also helpful for everyday decision making.**

Keywords- HCI Learning, HCI in engineering, constructivist learning, usability

I. Introduction

Throughout the years, learning has been explained as the analysis of several theories proposing various learning models. One of the aspects these models focus on is distinguishing between different degrees of activity/passivity in the role of the student [16].

Traditional or frontal teaching puts the students in front of an instructor who provides them with theories, concepts and a variety of content [8].

In this scenario, the students are mere passive receptors of information that a transmitting instructor presents and explains, be it with the help of old technology (blackboard or whiteboard) or digital technology (projector, computer, etc.) [1]. This way of teaching and learning that responds to a behaviorist-positivist model, has prevailed in education for decades, and is slowly experiencing changes and innovations that point towards a model in which the learner is the main actor and is active in his/her learning, constructing knowledge through change in the meaning of the experience, interaction with others and the organization and reorganization of his/her mental schemes [19].

In this new scenario, the role of the instructor is that of a facilitator of meaningful student experiences and a mediator or coach for the learners' construction of knowledge through practice, discussion, analysis, comprehension and active commitment [2], [16].

It is precisely in this context in which the teaching and learning of Human-Computer Interaction (HCI) in the field of Computer Engineering within the Faculty of Physical Sciences and Mathematics at the Universidad de Chile takes place. This HCI course has been a pioneer in Chile and Latin America. It has been given every year for the past 20 years, being constantly renewed and updated in synch with the newest prevailing technology. As a result, students have been able to learn of a wide range of general situations involved in Human-Computer Interaction that must be considered when designing any kind of software or device for human use. This implies development of a capacity for analyzing problems on a technical, cognitive and functional basis from a design perspective, and critically analyzing interactive Interface design methods and techniques.

The main reason why people do not use fully many specific systems is that their interfaces are not conceived and designed for end-users to interact with them, providing false cues for their use and mechanisms that lead to errors [4], [12]. The objective of HCI is to generate usable, understandable, safe, functional, intelligible and useful products. These are products with interfaces that are easy to interpret and understand, that provide visible cues for their operability, and that consider human error in their design [4], [18].

HCI makes it so that end-users are the center of any development and design [10]. This is to say that the design of the application is born of the needs and interests of the user, occurs with the user's constant participation and culminates in a high degree of usability [21]. For this reason, human-computer interaction favors systems with interfaces that are designed based on the user's needs, coming to know and understand the user, and even making the user part of the design team [7], [13]. In this way it is assured that the application is usable and understandable, and as a consequence, can be used by the end-user [4]. At the same time, these systems must be modeled and implemented by considering all the technical and functional specifications, and by following software engineering methodologies in such a way that a robust, functional and reliable system is obtained [5], [17]. The idea is to generate applications with interfaces that help, improve and widen the sphere of the user's experience, together with providing more reliable solutions, saving costs, improving the efficiency of processes, and most

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importantly improving people's productivity, efficiency and ways of life.

In addition to being associated to software engineering, human-computer interaction is heavily influenced by other disciplines of knowledge, such as the cognitive, biological, psychological, sociological, and anthropological sciences, as well as graphic and industrial design and ergonomics [15]. All these disciplines contribute to and inform the design of human-computer interaction by responding to questions such as: How does the human being behave in social and cultural contexts in time and space? How do his/her social relations and interactions occur? How do users perceive? How do they memorize? How do they process information? How do they know and learn? How do they solve problems? How do the brain and the sensory organs participate in their interaction with the software and with digital devices? How are the concepts, theories, elements and components of graphical and industrial design incorporated into the design of user interfaces?

II. THEORY AND PRACTICE

For Myers [11] it is important that students of computer engineering know and learn of the issues underlying user interfaces. This author points out that interfaces are the added value of computer systems, and generate competitive differences in that the hardware and software become commodities. His reasoning is based on the fact that if students do not know about human-computer interaction, their competences will not be useful with regards to the needs of the industry. Reality coincides with these arguments. The heavy commercial competition of modern technology products is based on the novelty, interactivity, usability and usefulness of interfaces. For example, the current commercial competition in the field of touch-screen interfaces and its various designs points to interface designs that are increasingly natural, usable and understandable for users.

One of the keys of our HCI course has been the learning methodology and its constant renewal, innovation and updating. This learning methodology consists of applying the theories, concepts and models studied in class to practical, applied, real and pertinent case study projects. On the basis of a global issue dealt with during the course, the students resolve and develop a series of HCI application case studies and a final human-computer interaction project that integrates and unifies the results of the previously developed cases, with increasing degrees of requirements, depth and complexity.

Just as today the tendency is for interfaces to revolve around multi-touch devices, technological changes are so fast and diverse that new and varied interfaces are constantly emerging. The field of human-computer interaction is especially sensible to the constant technological changes and innovations in the world of technology. In this way, learning of human-computer interaction implies that, in addition to attending classes, building up knowledge and managing information, students must be constantly reading papers published in the latest HCI journals and conferences in order to know of current HCI tendencies and issues.

The classes for the HCI course are given with a variety of nuances and orientations. Some sessions consist of presenting, analyzing and discussing theories, models and content, while others involve collaborative teamwork, planning, developing and evaluating progress on the design of the application case studies. Periodically the students revise and analyze their progress together with the instructor and teaching assistants, who support, mediate and facilitate the conceptual and functional decisions that students must make.

A. Application case studies

As has already been mentioned, the course presents the students with some application cases studies of a design or the redesign of human-computer interaction that the students must resolve. The students' work evolves from the design of human-machine interfaces to the design of human-computer interfaces. These case studies are organized into a central global issue, such as transportation, education and navigation that are finally linked in order to achieve a more complete HCI design, and produce it for the final project.

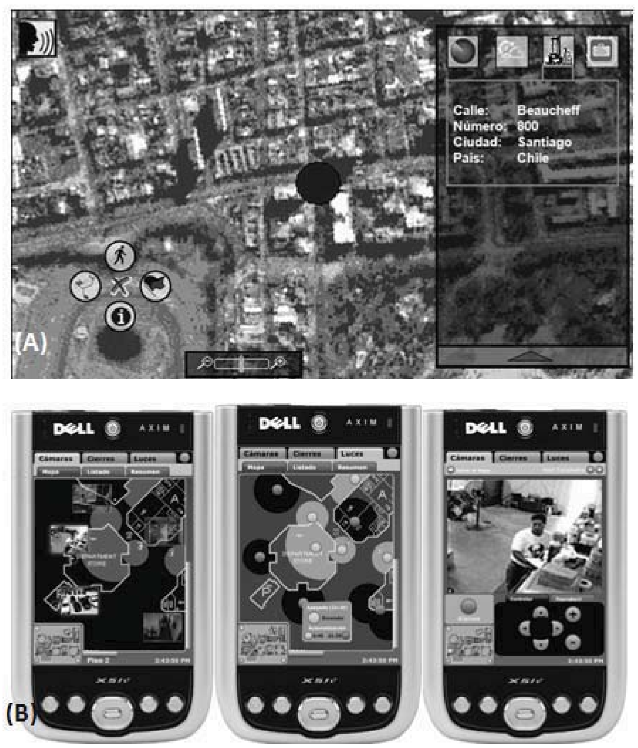

Figure 1. (A) Interface proposal for GPS devices developed by students of the course in 2006 (B) Proposed assisted control system for jails

All of the proposals for the resolution of the application cases from each team of students are presented, analyzed and discussed during the course. This implies that, in addition to learning about concepts and their application, students learn and reinforce their skills for designing and making presentations before an audience. As the course evolves and the application cases become more complex, the demands on the quality of the presentations increase, which obligates students to present, apply and use the course content studied impeccably and in great detail.

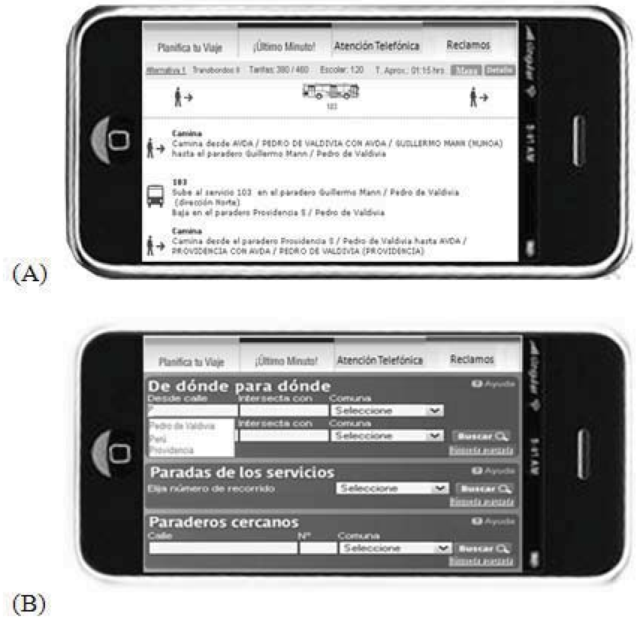

Figure 2. (A) Design of a mobile application in support of public transport (B) Proposal of a mobile design for the Transantiago website

The issues involved in the application case studies are varied. Students have designed and redesigned several web sites and portals, audio and information devices for vehicles, remote controls, multifunctional office equipment, remote home control systems, assisted control systems for jails, zoos and shopping malls, GPS navigation devices (see Figure 1), information systems for public transportation and systems related to education, among others. One of the key points of these case studies is that the designs must be user-centered, which implies working with and for end-users. The end-users evaluate the prototype designs providing their particular visions, problems, concerns, interests and needs.

The HCI case studies are not only varied, but are also related to real situations in real contexts. For example, in the year 2001 an analysis was made of the interfaces used in the new automatic charging devices installed in the newly replaced public bus system of Santiago. In 2007 the design of an application that would allow the user to locate the best route to/from work and home, as well as the best means of transportation, was studied.

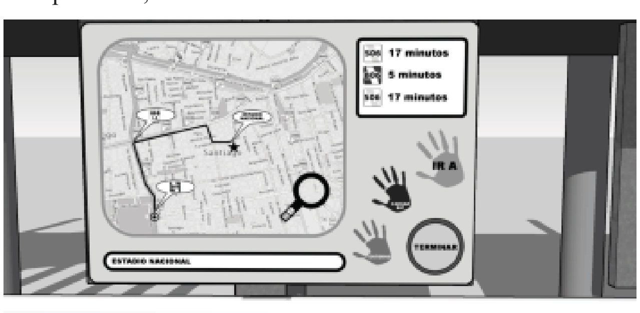

Figure 3. System interfaces designed by the students for the system-solution of a Transantiago bus stop

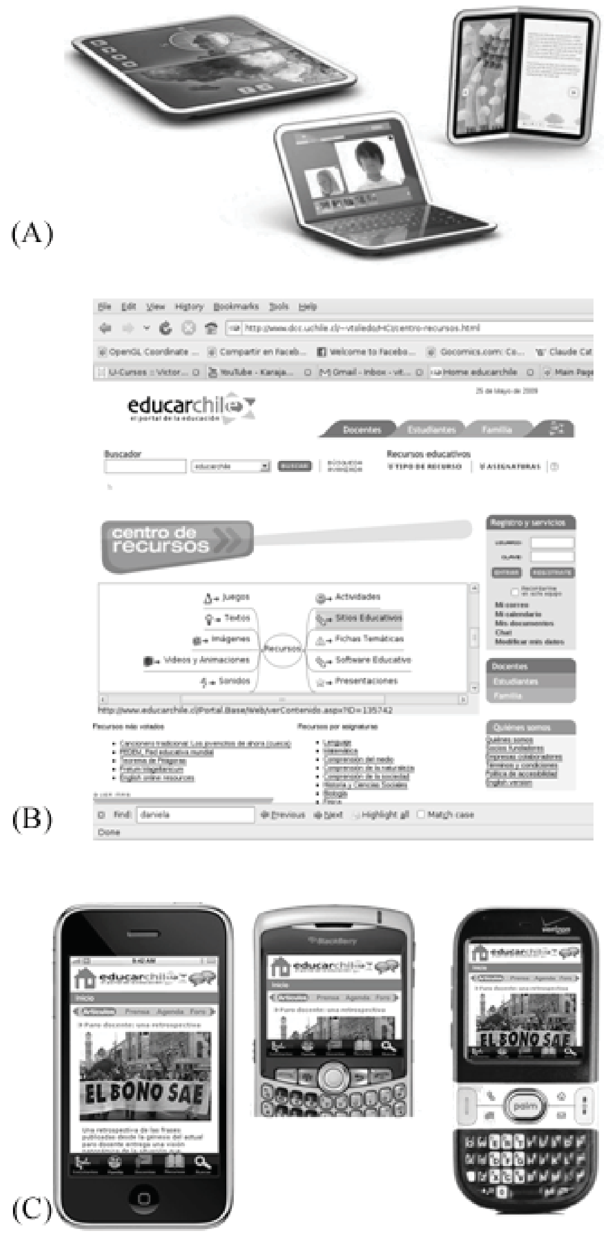

Figure 4. (A) Digital book interfaces designed by a team of students from the course. The students were not only concerned with designing the interface or the hardware device, but considered the context in which the technology designed would be used as well. (B) Redesign of the interface for the EducarChile web site. (C) Proposal of a mobile interface for the EducarChile web site

At the beginning of 2007, a new urban public transport system, called Transantiago, was implemented in Santiago de Chile [20]. This system emerged as a response to the almost unmanageable and chaotic situation with the buses that operated in Santiago up until the end of 2006 [6]. Thus, in 2008 the issue for the course was Transantiago (Figure 2A). Students evaluated and redesigned the Transantiago web site (www.transantiago.cl) (Figure 2B). The final project systematized, collected and linked all of the previously resolved application case studies during the course, resulting in a higher degree of complexity, as the design of a system-solution for transport focused mainly on providing information in order to help with decision making by taking passenger comfort, context and surroundings into account. To do this, students had to consider that the proposed interface must be implanted at bus stops and subway stations, in addition to other places that students deemed convenient (Figure 3).

Last year, in 2009, the central global issue of the course was education. Under this issue, the students designed an innovative interface for a device that would serve as digital text for high-school students. To do this, students had to find a technological solution that could be used as a book, a workstation, or an information search engine. This had to be done according to the user's needs, in order to be presented as a reusable resource with low maintenance costs, and the contents of which could be updated. To this practical problem, an important technological variable was added; the printed book upon which the device was to be based had still not been replaced by any existing digital technology, for which reason the device had to integrate a correct functionality based on a creative and innovative design. As a result, the students generated interesting and innovative interface proposals, in some cases using existing hardware devices, and in others they generated proposals for the development of new hardware (Figure 4).

Figure 5. Presentation of the redesign of the EducarChile.cl web site to the manager and professionals of the site from Fundacion Chile and the Enlaces network of the Chilean Ministry of Education

The second application case study this year consisted of students evaluating the interfaces involved in the educational web site of EducarChile (www.educarchile.cl), one of the most visited and used public web sites in the country. After this evaluation, the students redesigned the web site in their final project (keeping the end-users in mind: teachers, students and parents). The final project was presented to a group of professionals responsible for the EducarChile web site from Chile Foundation and the Education and Technology Center, coordinated by the Enlaces Network (www.enlaces.cl) (Figure 5). As a result of this experience, the web page managers redesigned the site to make it more usable, understandable and functional. To do this, the web page professionals created a survey in order to obtain more data and opinions from the end-users (http://www.educarchile.cl/Portal.Base/Web/VerContenido.aspx?GUID=c363e908-c2a3-4b21-bd56-ad0cd6ad6d94&ID=197268).

B. Evaluation

The evaluation of the main concepts studied in the classes is made through the use of the concept mapping technique [14] (Figure 6). In this way, the evaluation is not centered on how much the students remember or memorize, but on how they understand, organize, give hierarchical structure to, associate and relate the main concepts learned in order to construct meaning. Thus it is possible to know the representation of the students' mental conceptual home base for the concepts learned during the course. Each student ended the course with a concept map of the main concepts learned and its associations. This is to say, with a graphic representation of his/her significant learning of HCI concepts.

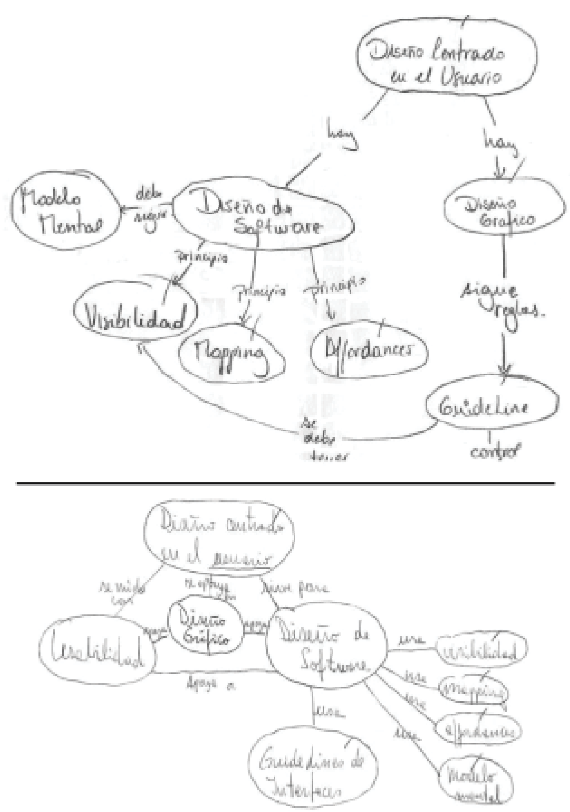

Figure 6. Concept Maps generated by HCI students based on the concepts studied and analyzed in class

Together with the evaluation of the contents seen in classes through the use of concept maps, the students have an intense workload regarding HCI readings. These readings cover the state of the art in the area of HCI and are recent publications from important conferences in the area, such as ACM CHI [3] and IFIP Interact [9], for example. As such, the students are up to date on the latest progress in the area, the latest technology for HCI that is being developed, and on user experience with different systems and applications.

III. OPINIONS OF EX - STUDENTS

There are several interesting and illustrative opinions offered by some students, several of which have already graduated, who took the human-computer interaction course. Regarding the learning methodology, the students stated that it is a distinct method and that it strongly supports the learning of several of the concepts seen in the course. *"It was a pleasure and a privilege to have been able to learn in that way"* (Victor Toledo, ex-student from 2009); *"The HCI course seemed interesting to me in the way that we studied real cases as a course project. It also allows one as a student to have a free reign on creativity and imagine innovative and interesting solutions"* (Juan Pablo Rodriguez, ex-student from 2008). In addition, the students recognize that the methodology utilized allows them to support the development of other skills that are fundamental for today's professionals: *"The Human-Computer Interfaces course is very interesting, in that it allows you to acquire and develop skills that are not common in other Computer Science courses […] the constant debates that are proposed and the presentations in the course allowed me to strengthen my oral communication skills, which is highly valued in the current labor market."* (Angelo Tadres, ex-student from 2007).

In more global terms, on the applicability of the course, students' opinions coincide in that it is a class that provides useful tools for engineers that have already graduated. Angelo Tadres, ex-student from the 2007 generation, says: *"As future engineers, they constantly teach us to design functional and quality software, but they never ask us to think of the users of these solutions. The HCI course gave me the necessary tools to solve these problems, thus creating much more usable and visually attractive interfaces". "In order to achieve a technical back-up to the intuition that I had before entering the University, the work I did in the Computer Science Department helped me a great deal, especially with the course and posterior workshop in the area of HCI. It was a great experience, putting the notion of what a software application does to leave the user satisfied and able to do his tasks into words and action"* (Ivan Galaz, ex-student from 2004).

Other opinions point out that what was learned in the course is useful for their current professional positions: *"The HCI course given by the Computer Science Department offers its students a vision distinct from software engineering, in which the experience of using the software is as important as the technical quality and its development […] In my case, I am in charge of the development of web applications, the usability of which must be strongly considered, because a poor design of its interfaces and interactions causes a loss of productivity in the systems when they are being used"* (Claudio Oyarzun, ex-student from 2004); *"The interfaces course teaches us to concentrate on what the user will end up using, the software interface, the weak point in many of the software applications that I have had to use"* (Mauricio Zuniga, ex-student from 2004); *"[…] HCI sensibility can always be a favorable tool, a plus among the qualities of a development engineer…and that today is quite scarce, and thus quite valued"* (Miguel Elias, ex-student from 2005); *"Up until I took this course, I was used to making programs oriented towards systems, concentrating only on making the program work. This was the first course within my specialty in which the focus was far from programming, but was rather on the end user's experience of using the program. This is a user who is not necessarily a computer expert. […] In my work I develop a lot of web applications, and this course has helped me tremendously in order to discuss important issues with other programmers, for whom it is hard to put themselves in the place of the end user, and who tend to design programs for themselves"* (Thomas Pieper, ex-student from 2002). *"I currently develop web applications, both for private companies and public organisms, and I am mainly responsible for assuring that the end user has the best information available when performing his/her tasks. For example, I assure that the usability level is included among the decision criteria when designing the flow for each task that the user will perform, that the controls for executing the actions are clearly available and that the actions performed by the user have a clear and precise system response"* (Ivan Galaz, ex-student from 2004).

These opinions reflect how relevant having studied human-computer interaction through a constructivist learning focus with application study cases and software interface design projects performed throughout the course has been for these professionals.

There are even some students who do not only adopt the knowledge and the experience learned in the HCI course into their professional lives, but who also use it on a much more personal basis. This is expressed through a higher level of sensibility to issues related to human-computer interfaces: *"At the end of the course I had already internalized the interface analysis into my daily life, not only regarding the web pages that I visit every day, but also regarding devices like MP3 players and cell phones that I use…something that I have continued to apply both consciously and unconsciously to this day"* (Miguel Elias, ex-student from 2005).

IV. CONCLUSIONS

This article presents an active way of teaching and learning human-computer interaction for computer engineering students. The learning methodology of the HCI course that is given in the Computer Science Department of the University of Chile allows for active, wide-ranging, concrete and up-to-date work that leads students to build up knowledge from practice. The course requires the students to constantly apply the knowledge they study in class. As a result, there is a deeper appropriation of the theory and practice of human-computer interaction.

Our end-users are the students. And their reactions and comments support the fact that the focus of the learning methodology is more centered on the practical work of application than on just the presentation and analysis of the course contents. They also highlight how this helps for the transfer of this knowledge to other areas of their lives.

The relevance of an HCI course in the formation of a computer engineer lies in that it provides another perspective on the systems and solutions that these professionals regularly design and develop. In embedding HCI concepts, ideas, theories and models, there can be more certainty that their developments will be used and understood by the end-users, and thus that their work will be more valuable, solid and sensible to them.

History is plagued with examples of technology applications for which use has been impeded because their interfaces are not usable, accessible, understandable, or because they do not represent the end-users' modes of interaction. An HCI course such as the one described in this paper can make all the difference.

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Engineering Education in the Developing World: The case for Biological Engineering

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Abstract— Engineering education in the developing world is not only necessary for economic growth, intellectual development and innovation, but is also fundamental for national security and short and long-term sustainability. Successful engineering institutions and productive engineers are not only necessary to create knowledge based economies in developing nations, but they are also important players in maintaining economic viability that is tied to national security of immediate and distant neighbors. The necessity for innovation in engineering education and grounding of this training in local needs and markets is true for all forms of engineering, including biological and biomedical engineering that have been rather recent inductees to the engineering education portfolio. Developing countries are taking biological and biomedical engineering seriously to address issues in food and agriculture, processing and nutrition and various aspects of healthcare and medicine. In this paper we address the need, status, challenges and opportunities for the developing world in bioengineering and biomedical engineering education and discuss ways in which the fundamentals of engineering education can be strengthened for a sustainable society.

Keywords: Biological Engineering, Biomedical Engineering, Developing World

I. INTRODUCTION

Engineering education, both in the developed and the developing countries, is intimately connected to not only innovation but also national security and sustainability [1]. The need to address pressing national problems, challenges and threats has always affected the way engineering curriculum is designed, implemented and executed.

While the practice and education of the next generation of engineers has been streamlined to some extent in the developed world, in the developing world, political, social and economic turbulence has affected both the education and practice in multiple forms of engineering. The key problems faced by the developing world are no longer their own problems. Instead they affect mass populations in both the developing and the developed world. Thus higher education in engineering that meets international standards and the local needs is critical to global security and sustainability [2-5].

In this paper, we look at the vision, challenges and future outlook of engineering education in the developing world, with an emphasis on biological engineering. The developing and the developed nations have seen a surge in research activity in biological and biomedical engineering over the last decades. The motivation for improved health-care, better pharmaceuticals, efficient technologies and higher quality of life is shared among the developed and the developing countries. In addition, the developing world faces issues associated with food shortage and public health crises that are less prevalent in the richer nations. Therefore biological and biomedical engineering education in the developing world is tied to national security, survival and sustainability in a way that is unique to these nations. This paper presents a mini-review of the current trends, challenges, opportunities and future outlook for biological engineering education in the developing world.

II. BIOLOGICAL AND BIOMEDICAL ENGINEERING IN THE DEVELOPING WORLD

Biological or biomedical engineering in the developing world can be broadly classified into two categories. The first one is engineering in agriculture and food sciences and includes areas such as genetic engineering and agricultural engineering. This area would also include food processing and food preservation, which are sometimes referred to food-process engineering in certain countries and contexts. The mechanical and electrical equipment associated with efficient food production are also topics of great interest but are outside the scope of this paper.

The second broad area that is of key importance to the developing nations is that of medicine, public health and pharmaceuticals. In general, there is little research on creating new drugs in the developing world, but recently there has been a surge of activity in the pharmaceutical industry in India, which is a notable exception. Other areas of biological engineering and healthcare include engineering approaches to diagnose, detect and combat infectious diseases, infant mortality as well as prevailing epidemics. Additionally, there has been significant activity in the US, Chinese and European research labs in creating low-cost point of care diagnostics for applications in the developing world.

Engineering education in the agriculture dates back to 1960s and 1970s with the appearance of genetically modified crops in the developing nations [6]. As a result, there are a number of agricultural universities in these countries, although the real engineering component of that education varies tremendously. These engineering institutions are also predominantly located in countries where agriculture makes the backbone of their economies [6]. On the other hand, issues related to public health have primarily been dealt with in medical schools and technology development or innovation has been limited. Engineering and medicine have also been kept as two disparate areas of higher education.

Despite a substantial need and dependence of national security, to date, there are no system wide studies of the status of biological engineering education in the developing world. This is probably due to two main reasons. The first one is the lack of appreciation of biological engineering in the general public. Biological or Biomedical Engineering still remains one of the lowest ranked engineering in the developing world. This is due to higher demand and higher paying jobs for engineers in electrical, computer, civil or mechanical engineering. The second reason is the issues of food and to a certain extent public health are not considered engineering problems and have been dealt primarily by economists, policy makers, politicians and bureaucrats. Since these critical problems are not dealt by engineering institutions, the perception among the general public remains the same where medicine and health are considered to be non-engineering disciplines.

III. CHALLENGES IN BIOLOGICAL ENGINEERING EDUCATION

The current challenges facing biomedical and biological engineering education in the developing world can be divided into three categories. They can be summarized as input and output challenges and curriculum and teaching issues including teacher quality, training and retention and research related problems.

A. Input and Output Challenges:

The first major challenge for biological and biomedical engineering education in the developing world can be classified as input and output challenges. These challenges are associated with the quality of students coming into the program, their abilities, aspirations and overall quality. The output of these institutions into the marketplace and the society in general is also linked to the overall perception of the programs and their quality. While the overall level of education in the developing world is highly variable [7], the number of students reaching university is fairly low [7]. In addition, due to economic pressures, students often choose certain areas, including certain engineering degrees, for their majors. Top quality students rarely opt for biological engineering or biomedical engineering as the majors of their choice. There are several reasons for this decision. The salaries associated with biological, agricultural or biomedical engineering are modest in comparison to other engineering fields, particularly computer and electrical engineering [2]. The general perception of the field and the associated parental pressure also plays a role in students opting for areas other than biological engineering. Since historically biological engineering has been associated with agriculture, there are fewer jobs available in the urban areas.

There is also active feedback between the output and the input. Since the input is often of mediocre quality, the output is not particularly impressive either. Due to other factors listed above, including lack of opportunities in the urban areas, the salaries are relatively low and the accessibility to top schools, hospitals and recreational facilities is limited. As a result the system as a whole is unable to perform coherently and the overall quality of the system continues to decline.

B. Curriculum and Teaching Issues:

The problems and challenges are not limited to inputs and outputs. There are numerous fundamental and perhaps fatal problems in the crucible that converts these inputs into outputs. Among these, curriculum presents one of the most fundamental problems. The curriculum is often dated and obsolete. There are few, if any, mechanisms for updating or reviewing it in regular intervals. In many instances, it is not even clear where the curriculum came from and how it was designed. More recent versions of the curriculum are often carbon copies of what is offered in the top institutions of the world with little regard to local needs or problems.

This lack of adaptation has two major consequences. The first is the output of the curriculum is an engineer with little appreciation or knowledge of the local challenges. The second is the inability of proper execution of the curriculum due to incompatibility of resources between the institutions where it was designed and the institution where it was offered.

The teaching staff at most biological and bioengineering institutions in the developing world is graduate of the same system. This cycle, due to low input and output quality, and massive inbreeding, results in continuous deterioration.

C. Research Activity and Research Incentives

The institutions engaged in providing biological engineering education have historically not been particularly research active. One of the main reasons for this lack of activity is limited number of graduate students enrolled in these institutions [8]. Lack of funds and weak industry has also led to disincentive for original research. Publications in peer review journals are also rare. Most of the research is carried out in government labs and in some cases in private industry. This situation contributes to the poor quality outputs from these institutions, and in turn affect the overall performance of the engineering education sector.

IV. Sustaining Biological and Biomedical Engineering Education

The current status of biological and biomedical engineering education in the developing world is far from satisfactory. The success and sustainability of biological and biomedical engineering education would fuel economic growth and substantial improvement in the quality of life. There are three major ways in which quality biological and biomedical engineering education can be improved and sustained in the developing world.

1) *Partnerships*: A large number of international organizations, ranging from WHO to Gates foundation are providing funds to address problems of biological and biomedical engineering in the developing world [9]. These grants are largely focused on pressing problems in food shortage and security and public health. A number of universities and researchers associated with biological and biomedical engineering from across the globe apply for these grants and provide tangible and high impact solutions to the pressing problems. However, very few of these grant and partnerships include active biological and biomedical educational components. The educational components included in some of these grants are also limited to vocational training but exclude areas of higher education and long-term educational sustainability. As a result the experience of the researchers from top institutions in biological engineering, who are also often engaged in educational leadership are never fully utilized.

By encouraging governmental and non-governmental organizations to involve local researchers and universities in their programs would enhance cooperation and give opportunities to local researchers that are otherwise isolated from the biological education and training. Similarly, memorandums of understanding and economic aid packages targeted towards the healthcare problems in developing nations should include teacher training and quality assurance at the higher education level. This can be achieved through engaging researchers, in the developed countries, in the areas of biological and biomedical engineering, who are interested in addressing problems in the developing world. Encouraging educational partnerships, in parallel to research partnerships, would provide a unique and comprehensive understanding of both education and practice of biological engineering to the developing nations.

2) *Teaching grants*: A number of federal and local governments in the developing world offer financial incentives, including grants to address problems in biological and biomedical engineering. However, the incentives to modernize curriculum, train teachers or develop educational components at the higher education level are often ignored. Such mechanisms exist at primary and even secondary education through incentives from international agencies (such as UNESCO and the world-bank) but modernizing curriculum and encouraging debate on curriculum and teacher training at higher education level are overlooked. Since biological and biomedical engineering appears fairly low on the priority list, the issues related to curriculum and teacher training are in worse state than other engineering disciplines. A top-down encouragement, in the form of grants, would allow university professors to take a serious look at the curriculum and encourage discussions. Alternatively, as a number of countries have encouraged research activity through federal grants, incorporating mandatory educational components in those grants would require researchers to think seriously about curriculum and efficient teaching.

3) *Industry Linkage grants*: Private industry in the developing countries or their developed neighbors are often interested in untapped markets. With agriculture and healthcare as key investment opportunities for countries with low-income neighbors, developing local expertise is a cheaper option than importing talent. In this regard, both private industry and local governments have a role to play. These key players should play a more vital role on reviewing the curriculum of local engineering institutions to ensure that the output is cognizant of the local needs and challenges. Industrial teaching internships for professors aimed at making professors aware of the challenges would lead to noticeable changes in the curriculum . With these linkage projects it is likely that the curriculum would adapt to both the fundamentals of biological and biomedical engineering as well as the local needs and challenges. In the long-term this would benefit the private sector by providing it with a work-force that is innovative, fundamentally sound and aware of the challenges faced by the local industries.

V. Conclusion

Biological and biomedical engineering will play a pivotal role in the development, survival and sustainability of the developing nations the in upcoming years. Issues related to food production, safety and security, public health, epidemiology and overall life quality and expectancy are areas where biological and biomedical engineering will play a central role. Increased globalization and rapid growth in these sectors in the developed nations will also have an impact on the practice and education of engineering in the developing countries.

As the government and non-government sectors realize the importance of these areas, more schools, colleges and departments will incorporate biological and biomedical engineering into their mainstream curricula and degrees. In a rapidly changing world, where the issues of food and healthcare are affecting nations across continents and influencing policy debates ranging from national security to immigration, biological engineering will have a central role to play in the developing countries. A shift in perception of biological engineering from a second class engineering to the cornerstone of national security and sustainability will lead to newer challenges in educating the next generation. As we approach that stage, it is more important than it has ever been to focus on quality control in curriculum and teaching and connect the curriculum with national and local needs and challenges. Quality assurance, well organized and up-to-date curricula and partnerships between public and private sector are necessary to shape the landscape of engineering in a way that makes a substantial impact on national security and long-term sustainability of the developed nations.

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Developing Global Teamwork Skills: The Runestone Project

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Abstract— **The Runestone project is a collaborative course currently offered by Universities in Sweden, Finland, and China. The course provides a unique opportunity for third year engineering students from a variety of programs to experience the opportunities and challenges that international teamwork involves. Teams composed of students from two countries work intensively over a 10 to 13 week project cycle to develop a system which allows a user to remote-control a LEGO NXT robot. The teams negotiate the features of their final system with the academic supervisors from the participating Universities, propose a development time-frame and deliverables, and develop and demonstrate a prototype system.**

This paper uses teaching and learning findings from engineering education research. The evidence is used to arrive at an instructional design that aligns learning outcomes, with instruction and assessment to support student's learning outcomes development throughout the course, We also discuss the evolution of the course over the past 12 years as we moved from a pilot version with eight students from two universities to a large scale course with between sixty and eighty students from between three and five universities distributed over three continents and widely different educational and social cultures.

Keywords— **engineering skills, educating the global engineer, global virtual teamwork**

I. Learning Outcomes and Motivations

The quality of engineering education, and the relationship of curricula to competencies valued by industry, is increasingly important as the world moves towards a more student centric and socially relevant style of education [1]. Quality assurance of outcomes is also an important driving force, as many nations transform their education in response to the Bologna process [2]–[6]. One important element in the learning trajectory from novice to expert is experiencing the uncertain nature of problem solving in a loosely constrained environment.

Some common features of professional work that are seldom represented in University classrooms and practical exercises are associated with the more open ended problem specifications that can arise. Equipping students with a range of important professional skills, such as project management, teamwork and cross-cultural communication can be achieved in a carefully managed open ended project course.

Industry problem specifications are often stated in rather fuzzy high level terms. An open problem specification places different demands on learners than traditional practical work or course assignments. The course we describe in this paper scaffolds learners' development in a number of aspects of professional working practice. During the course we mentor students through the analysis of the problem space and proposal of a feasible solution, identification of appropriate tools and techniques with which to solve the problem, managing and working in a team, and learning about working with people from different cultures.

The objectives of the Runestone course are to give students experience with a problem and work situation which requires them develop a greater level of self-reliance, teamwork, negotiation and communication skills, integrate and use theoretical knowledge from earlier courses, and (through experience of a wider systems development project cycle) understand that the theories we teach in subjects like software engineering are not prescriptive and do not always lead to timely delivery and successful products.

Through the Runestone project we provide students with significant and valuable experiences, directly relevant to their future working life, while retaining some of the benefits of a ”safe” educational environment. By ”safe” we mean that students can experiment with applying their theoretical knowledge to a systems development task in a supportive environment where they do not risk losing their job, or failing the course. Students are not, however, left to “sink or swim”, active bi–weekly mentoring meetings (Milestones) are used to support and guide students as they struggle to develop the skills they need.

The assessment criteria are designed to stimulate and reward students who engage in processes and activities that contribute to their development of insight and skills for dealing with the realities of systems development in a globally distributed virtual team environment. This means that a student can complete the course, and gain a pass, even if the system they deliver falls short of achieving the functionality and quality required to release a product. Passing the course depends much more on working processes and sincere attempts to put theory into practice, than it does on developing a successful and robust hardware/software system.

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II. Runestone

Research on designing learning situations that help develop professional engineering skills such as teamwork, cultural awareness, and project management is a key area as we design programmes to educate the next generation of engineers. Grandin et al. [7] identify a number of key areas in a recent report where they call for action to address the needs of future engineers. Part of our approach to addressing these educational challenges in the IT programme at Uppsala University is the "Runestone Project", a collaborative course in engineering systems development spanning multiple Universities and cultures. [1] Runestone is based on the well publicised idea of providing motivation and scaffolding for the development of professional skills through open ended group project work [8], [9]. This paper provides an overview of the models [10], [11] educational theory behind the course design and an overview of its current structure. One unique aspect of this course is that is has been offered continuously over the last twelve years, expanding from a pilot course with a single group of students to a full scale collaborative course with 60 to 80 students participating from four nations.

Runestone students complete a team role and skills evaluation exercise at the start of the first week of the project and are subsequently placed into teams by the instructors. Teams have approximately six members from two sites, and are supervised by an instructor from the teaching team, with whom they have regular virtual meetings throughout the course. Assessment and mentoring of the teams occurs in the virtual meetings. Staff and students do not meet physically very often during the course, indeed many of the students might be in another country than the staff member supervising their team.

The course requires students to design and implement a large scale distributed system. The task is closely related to a realistic engineering work assignment [12], and requires knowledge of many aspects of their previous study in distributed systems and network programming. The course provides students with experience of team based product development, in a modern technical work environment where teams are both culturally diverse and geographically distributed.

The course combines application of technical skills with other important global engineering skills: teamwork; negotiation and project planning; and project execution.

Technical

In recent years teams have developed a software system to give users remote control of a robot, build using LEGO NXT, in a location anywhere in the world via the Internet. The project used in the early years was based on custom built hardware. However, maintaining and coordinating acquisition of these systems for all the collaborating sites became too complex after a few years, and we replaced the custom hardware with LEGO Mindstorms robots in 2003. A further transition to LEGO NXT hardware in 2007 was motivated by difficulty of obtaining the, now obsolete, Mindstorms RCX hardware. Wear and tear on the LEGO RCX kits, and the availability of bluetooth communication in the LEGO NXT, replacing the infra-red communication used in the first Mindstorms platform, were other reasons for the change.

The specification has undergone several revisions over the twelve years we have been running the project, but the salient characteristics and their relationship to learning outcomes and assessment policies has remained largely unchanged over the last ten years. The project has a ten to thirteen week timeframe. The activities and deliverables for 2005 shown in 1 are typical. There are slight timetabling variations from year to year depending on the level of synchronisation of the academic timetables at the participating sites.

The current task requires teams to design and implement a software system which allows a remote user to control a LEGO NXT robot (of their own design) in real-time through a web browser Graphical User Interface (GUI). Communication between the robot and server is implemented using the BlueTooth wireless communication protocol. Communication between the server and GUI can be implemented in a variety of technologies. Since a real-time video stream of the robot environment is to be incorporated in the GUI some low level network programming using sockets and the UDP and TCP protocols is also required.

Teamwork

Teamwork and the process of collaboration is closely observed during the project and the teams are required to report regularly. Regular mentorship is a key element of the course [13] and helps the teams to negotiate a range of issues that arise from the technical challenges and personal and cultural differences. Active and regular mentorship feedback is a crucial element of the learning activity in the course, providing information and helping students to negotiate the technical and personal crises that arise naturally during the course.

Development of written communication skills is facilitated through critique of the design documents and bi-weekly reports the teams present. Each report is presented using online synchronous chat, this allows the instructors to evaluate team member's communication skills and ability to organise and use time effectively. The instructors also observe the internal social dynamics of the team, and provide feedback and advice.

Process Management

Problem analysis and specification documents are requested early in the project and critiqued, each deliverable, including documentation, verbal presentation and collaboration processes are incorporated in the final team grade. Teams are also asked to provide an implementation timeline in the form of a "Gantt Chart", in which the major sub-project dependencies should be identified. Instructors use this chart to assessing the team's ability to make progress, estimate time requirements, and adjust work-flows as time mis-estimations become apparent during the project.

[1] The course is a collaboration between Uppsala University, Sweden, Grand Valley State University, USA, Rose-Hulman Institute of Technology, USA, Tongji University, China, and Turku University, Finland.

Project Week	2005 Dates	Activity
0	9-13 Jan	USA Only: Intro
1	16-20 Jan	Intro and Team Building
		Course begins 19/1 in Sweden
2	23-27 Jan	Work on Team Building experience (no IRC[2] meeting this week)
		Prepare Web site and CVS for team
		Work on Analysis and Design
3	30 Jan -03 Feb	Milestone 1: Present Team Web Site(IRC report)
		Present Individual Team members and their profile pages
		Work on Analysis and Design
4	06-10 Feb	Milestone 2: Present Analysis and Design Docs (IRC)
		These deliverables are marked contributing 10 marks
		to the final group grade
5	13-17 Feb	Continue work (no IRC meeting this week)
6	20-24 Feb	Present Milestone 3 (IRC report)
7	27 Feb-03 Mar	Work on project sub-system integration
		Prepare your final presentation materials
8	06-10 Mar	Spring Break in the USA. Sorry Swedes!
		Teams work informally, maybe mostly in Sweden?
9	13-17 Mar	Present Milestone 4 (IRC report)
10	20-24 Mar	Final Presentations

Fig. 1. Project timeline

Instructional Approach

Few resources are provided initially. Students are expected to locate and make choices of the software and operating system to use with the LEGO NXT processing unit, as well as communication protocol stack to handle communication between their software system and the robot. We provide links to some appropriate software, but nothing is specified in the project description. The instructors assess the technical learning outcomes based on the level of sophistication of the software and the complexity of the attempted functionality, as well as the degree to which the software is complete and working at the end of the project.

Development and assessment of skills such as teamwork and intercultural communication are based on continuous online mentoring and discussion in the regular virtual meetings throughout the course. Assessment of outcomes is based on observation of how the teams deal with communication and work process issues in the presence of tight deadlines and high workloads.

Managing this process for a team of instructors also presents challenges. To make judgment of skills and deliverables comparable between instructors the teaching team have regular online meetings, and discuss the interpretation and application of the qualitative grading criteria (see figures 2 and 3 for examples of some of these grading rubrics). Many of the larger deliverables are assessed by several instructors, for instance the design documents and final presentations are usually assessed by the instructors for both the sites involved in each team. Finals marks are discussed if there is a difference of opinion between two instructors. Our experience is that instructor agreement rates are very high, we have never had serious disparities or disputes over marks for design documents or final presentations.

A key element of the Runestone approach is the course assessment framework. Our assessment structure focuses on aspects of the project work including technical achievement, work process, teamwork, and communication and cultural sensitivity which are vital to future practicing engineers. In the following section we examine some aspects of the course structure and assessment activities in more detail.

III. Assessment

The project work-flow and deliverables used to assess teamwork and software development processes are summarised in figure 1. The dates given here are for the 2005 academic year and provide a guide to how the sequencing of courses was managed between Sweden and the USA. Coordination between Sweden and participants in China and Finland is easier as students from the participating universities have had greater flexibility in their study timetables.

Assessment is based on a combination of individual and team achievements in a range of areas. The goal is to provide motivation for students to engage in both the technical and non-technical aspects of the project in order to achieve the desired learning outcomes. Assessment is divided into three primary areas.

Teamwork and Communication :
evaluating the organisational ability of the team and the manner in which the team presents itself and works as a unit to achieve its goals. This includes individual marks for those elements of the reporting for which individuals are responsible, as well as peer

Grade	Classification	Qualitative criteria
0	Missing	No report from group
1	Inadequate	Poorly structured, several required areas missing or incomplete, some material not online prior to the meeting.
2	Poor	Poor to adequate structure of material. some required data missing or hard to find. Confusing presentation and layout of pages hard to read.
3	Adequate	All required information is presented and adequately organised, however, layout and structure make it hard to evaluate the accomplishments of the team since the last report.
4	Fair to Good	All information is supplied and structured according to the reporting requirements. Some areas of the report do not give sufficient relevant information for the reader to assess the progress of the team and the individual contributions of the members since the last milestone.
5	Excellent	All information is supplied in a format and structure that is consistent with the reporting guidelines for the course. Information content is relevant, concise and gives a clear and accurate impression of all aspects of the achievements of the group and individuals within the group since the preceding milestone.

Fig. 2. Criteria for awarding team grades at each project Milestone

evaluation of the contribution of each member by the other members of the team (at the conclusion of the project).

Project Management:
evaluating the interim progress reports and the online meetings in which the team reports on progress. Assessment here focuses on the ability of the team to plan realistically and work towards reaching the milestones they have defined.

Technical Achievement:
evaluating the complexity of the milestones the team set, and the levels of technical achievement reached during the product development process. Assessment is based on professional code development and the sophistication of the final product.

Contributions by individuals and teams in each of the assessed areas are evaluated throughout the course using the following deliverables. There is no written final examination in the course, deliverables in all projects are evaluated throughout the course, and the final project demonstration plays a significant role in determining the final grade. Individual grades are based on the group grade, to which modifiers are applied based on peer and instructor assessments of individual contributions to the project development and ultimate success.

A. Teamwork and Communication (30 points):

- Milestone Meetings (20 points)
  There are four milestone meetings, and at each of these the teams gain between 0 and 5 points depending on the performance of the group. This gives a total of 20 points. After each meeting an online critique of the meeting and report is made available to the team immediately via private pages on the course Wiki. The critique provides written feedback on the presentation, as well as the assessment of the instructor (in the form of a grade on the 0-5 scale).
  The qualitative associations we use to allocate a grade on the five point marking scale are shown in figure 2.
- Individual Achievement (10 points)
  At the end of the course, each individual's contributions to the meetings, and their level of engagement in the project are graded.
  A mark of 0 to 5 is be allocated by the teaching staff on the basis of their assessment of each individual's contribution to the project in terms of attendance and participation in group meetings, and contribution to team spirit and success.
  A further mark of 0 to 5 is be awarded on the basis of the peer reviews of each team member by their teammates. This gives the remaining 10 points in this category. We have studied how students approach the anonymous peer review [14]. In our experience this aspect of the course works well, and students typically give a balanced and responsible assessment of the contributions of the

Max. Points	Criteria
5	Research an area and write-up a report describing what you learned
6	Research an area and include that research in the design document
8	Research an area, include it in the design document, and create a working prototype apart from the project itself
10	Research an area, include it in the design document, integrate it into the project

Fig. 3. Grading criteria for Areas of Excellence

individuals in the team.

B. Project Management (30 points):

The **team progress grade** reflects the extent to which the team has demonstrated good project management practice in their workload allocations and priority setting.

A mark from 0 to 10 is awarded on the basis of the quality of the project analysis and project specification documents prepared by the team.

The remaining twenty marks are earned during the project based on the extent to which the team has achieved its self defined goals for milestones three and four. This mark is based on the demonstrated achievements of the team being consistent with the expectations stated in their development and implementation plan.

C. Technical Achievement (40 points):

Twenty (20) marks are awarded for the final presentation and the product demonstration. Criteria for assessing final presentations are included as appendix A. Two instructors are two teams participate in every one hour video conference presentation slot. The teams make a presentation of their development process, and reflect on their project and what they have learned. Each presentation concludes with a live demonstration of the software, and questions from the other team.

The tools we have used for video-conferencing in the final presentations have varied considerably. In early courses we used a combination of Microsoft NetMeeting. Later versions of the course used either Skype or Marratech. In 2010 we will use Adobe Connect.

Another twenty (20) points are for technical innovation and high quality technical achievements in two nominated areas of “excellence”. As a part of setting milestones or goals, the teams will be asked to identify two areas of the product where they intend to aim for advanced development leading to “excellence” in the resulting technical solution. Marks are allocated in these areas according to the guidelines in figure 3.

CONCLUSIONS AND FUTURE WORK

The Runestone project approach has been incrementally refined over the last twelve years to provide students with global teamwork experience in a realistic project setting. The course has expanded to involve universities outside the original partnership, and now involves up to four universities and between sixty and eighty students annually.

The main contributions of the current paper are to completely describe the current structure and assessment strategy for the course and link this to learning outcomes in communication skills, global teamwork, and virtual collaboration. By publishing this course model we contribute to a growing literature on the use of open ended project work in preparing students to work effectively in the workplaces of the future.

APPENDIX

A. Presentation Grading Scheme

3pts Professionalism in preparation and presentation.
1) Was the team well prepared and organised.
2) Smooth and well rehearsed presentation structure.
3) Use of presentation tools (IRC, NetMeeting, hardware demo)

5pts Use of web and audio-visual presentation technique.
1) Was material clearly presented and easy to understand. (i.e. pictures, good slides, etc.)
2) Is the presentation clear, to the point
3) Does the presentation show off the whole team, and each person’s accomplishments/contributions.

5pts Team Management
1) Division of labor
2) Leadership
3) Time and scheduling difficulties
4) Personality conflicts

5pts Technical Discussion and Demo
1) Design process
2) Coding standards, version control, software management issues
3) Software package and documentation standards
4) Limitations and future enhancements
5) Demonstrated software functionality

2pts Question and Answer
1) Posing good questions to the other team.
2) Responding well to questions from others.

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Technological Development, Sustainability: Discussions about International Aspects of Engineering Education

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Abstract — **Engineers are among the main agents of promotion of development in the world and the formation of a new kind of engineer is the priority to face the future economical and political market. Nations are recognizing the importance of engineers once they are the ones that make possible the world goes round. Engineering Schools worldwide have implemented more flexible programs, more investments in labs and equipments, promoted more exchanges programs and so on. It is the education evolution in order to adequate the formation of engineers of the 21st. Century. This work discusses an important issue as the engineer formation under the perspective of the international academic midst. COPEC – Council of Researches in Education and Sciences has a history of action in engineering education, conceiving and implementing projects with success. However, more and more it is necessary the permanent attention to the changes in world scenario concerning the political, economical and social aspects of the country and the globe. This awareness helps to develop and implement new programs in order to form the engineer for tomorrow. Although it is not an easy task it is the way to assure the future of engineering as well as the development of science and technology.**

Keywords: Global thinking; local awereness; contemporary paradigm; sciences sdvancement; generalist formation; strong ethics.

I. INTRODUCTION

The discussions about Globalization in general show a bad scenario and the future is unpredictable once it is not possible to foreseen the big players' next movement in such huge business game of fighting for markets. The world is changing quickly, the distances are smaller and so we have a larger number of people moving around, interacting with different cultures and habits and at the same time having a kind of influence. Big corporations are looking for new talents no matter where they are and so more opportunities and the reverse side of the same coin more competitiveness. The history shows an enormous amount of companies and engineers working in different places in the world accomplishing huge projects promoting the development of countries and societies. Now more then ever engineers should pay attention to what is going on worldwide to go for international experiences to improve personal skills and get different opportunities because nothing has more impact than personal experience [01].

It is necessary to promote changes in the way engineers are educated at the present. There is a need to break up the old paradigm of education that perpetuates the mere technocratic formation. Following these thoughts there are some questions to be considered: 1. Does this process of change really occur at the level of modern engineering education and training in different countries? 2. Are the engineering students aware of the contemporary skill requirements of engineering experts? 3. Does any program consider how much the new socio-occupational demands affect the professional formation of future engineers? These are very important aspects to take into account when real actions are taking place in education reforms regard to engineering programs. Although a little slowly the changes will have to happen in order to attend the demands of the 21st. Century [02].

II. COPEC- COUNCIL OF RESEARCHES IN EDUCATION AND SCIENCES

The Council of Researches in Education and Sciences is constituted by scientists of the several areas of human knowledge committed with education and the development of science and technology. Its members believe that education is the main beam in the construction of a better society and that sciences and technology are the big agents in the fostering of progress to promote the welfare of human being.

The history of COPEC has started with an idea shared by some scientists of creating an organization to foster the research mainly in education and sciences. This idea seized proportions and after some meetings the Council became reality. It is a group of scientists, professors and professionals whose vision of future has driven them to start this work. Through its activities COPEC maintains relations between universities, institutions of education, enterprises and the society of the several countries for the discussion of education, technology and sciences directions. It works to stimulate and to foster the efforts to bring an international perspective in education [03].

Constitute powers of the institution:

- General Assembly;
- Deliberative Council;
- Board of Directors;
- Fiscal Council.

III. ENGINEERING IN FOCUS

Sustainable development with social promotion of individuals and society has been the constant search of scientists, educators and some politicians worldwide after the globalization phenomenon has started. Despite the efforts of so many sectors of society the present status of Education in every level in western world is not yet as good as it should be. Education plays an important role in the development of peoples worldwide. It is the key to combat ignorance and consequently the poverty. Science and technology alone can not help. It is fundamental the growth investment in education for all.

Technological power may shift from the west to the east as India and China emerge as big players in the global market. The two countries have the size and weight to transform the 21st global economy. This aspect will certainly have an impact on the education in western world too. Although the reality is that India and China will always have an advantage in their numbers, by the other hand in western world there are the freest markets, the most highly trained workforce, the resources and ability to innovate, and the best universities in the world.

History facts show the innumerous achievements of so many engineers all around the world who have diligently built and transformed the environment to make men's life better. The number of prominent professionals who have been referenced by their accomplishments is uncountable. Based on this it is possible to say that the formation of engineers is fundamental to keep the level of development of humanity in order to achieve the social development similar to the technological. However the present challenges of engineering education institutions are not limited only to the formation of a professional for a new global work market, but also to defeat the crises of education in which they are inserted. The crucial problem is the necessity of think again the kind of education which has fragmented knowledge that drives people to an inability of articulating its several parts. Education must promote the natural ability of the mind to set and to solve problems and by inter-relation to stimulate the full usage of general intelligence [04].

IV. THE ROLE OF UNIVERSITY

People live today in a world of no frontiers, with new complete new values and different social relations. All these aspects promoted by the development of science and technology have modified deeply people's life in all levels of the so-called "Global" society. Education institutions are challenged once more, to provide for the society the new citizen forming the professional prepared to face the unpredictable challenges of the future and to be a winner.

University has an important mission that goes through the centuries, from past to future, passing through present. This mission is essentially the conservation of cultural inheritance generating ideas, values and knowledge. This same University has to defeat the challenge of present world serving the contemporary society viewing the future.

New World order demands a new kind of professional, capable to think global without loosing the dimension of local peculiarities and vice-versa. It is not easy to form this kind of professional although it is known exactly what is necessary. With the goal to defeat this challenge COPEC has implemented many projects in different Engineering Schools that were very challenging. They were programs that required the full commitment of the school team. Others that required substantial financial investment in new equipments but all of them were accomplished with success [05].

V. AN OVERVIEW OF SCIENCE, TECHNOLOGY AND ENGINEERING

As any Country Brazil has recognized the importance of engineering in world scenery and so it has been working to get the competitiveness of national goods and services by means of incentive to create projects of qualification of professionals through continuing education for example and others. Leaderships, many representative groups, and agencies have been implemented programs to prepare the engineers to increase the efficiency of research system, experimental development, engineering, producing system and market.

All these efforts have been having a kind of smooth effect once it is one of the most difficult programs of College level and expensive that does not help very much the inclusion policy. However, some Colleges have opted for a softer engineering program offering them in the evening. These programs are lighter, more focused in technical knowledge, and less focused in basic sciences. The students in general work all day and choose engineering programs because it is a way to be promoted at work [06].

A third degree diploma opens some doors, it means not only the possibility of earn more money but also to reach an upper status, socially speaking. It is a fact that even being a lighter program for the students it is very hard and in general it takes them more than five years to finish it. The diploma has the same value of a program that prepares engineers of conception. In certain way it helps the inclusion policy of education although the number of engineers has been decreasing considerably in the last 10 years [07].

VI. ENGINEERING EDUCATION PROJECTS DEVELOPED BY COPEC

COPEC is an organization that develops many activities on several fields of sciences like environmental, healthy, oceanography, computer sciences and others. The group that is involved with engineering education is very active and counts with a profile of many positive achievements. Along almost 5 years the group of engineering education researchers has developed many successful innovative programs that were implemented in different universities. Some of them were in under graduation level such as:

Fishing Engineering – it was a five years program, which main characteristic is the inclusion of extra classes specially selected as aquiculture and business management and the effective work in projects. The work in projects was developed in a fishing community or in fishing caught industry, supervised by a professor.

Computer Science Engineering – five years program, totally ministered in a traditional way with the insertion of Digital Systems course taught at distance in a first moment and lately with the introduction of Communication Systems course. They were available in punctual and non-punctual systems with tutors to help to solve doubts and intermediate the student – professor interaction.

Electrical Engineering – five years programs that had what was called "free period" that was a time when the students could attend classes in the several areas of human knowledge, in one of any other college department of the university. They could choose as many areas as they wanted along the five years, at least one per two years; at the end of the each period they have to present a report about their development. The report was showed and discussed with a council compounded of a psychologist, a pedagogue, an engineer professor and the coordinator of the program.

Environmental Engineering – five years program designed to have modular periods; the "theoretical module" and "research module". The theoretical basis of the researches that the students developed was given to them during the "theoretical module" and the two modules happened in alternate periods. It is as follows: at the fourth year the class was divided in two groups of students half in "theoretical module" and half in "search module" and they shifted at the following period of four months. At the end of each "search module" the student's performance was evaluated so that the following module approach could be in according to the necessities of the students.

Biomedical Engineering – five years program that included the "Challenge Cycle", which is a period of four months at the end or in the beginning of the last two years. It was a period when the students worked effectively in a hospital or research center. A professor altogether the supervisor of the institution supervised the students' work in part of a project. They had to accomplish their work so that another student that would replace her/him in the project could perform the next step. At the end of the program the student was a professional with full formation in electrical engineer, with strong knowledge in bioengineering, medical and health.

Electrical and Civil Engineering – five years program, the curriculum was elaborated in a way that the experience in "Scientific Introductory" was part of the program as a course. It is a way to form the Engineers in which the students since the first year of the program had to develop projects and to present them at the end of the each year for an audience. They had also to develop prototypes of devices and show them working. Their scores were based in the design, the prototype performance and the student presentation. Every year it resulted in proceedings edited and distributed by the university.

Environmental Engineering II – five years program with the adoption of new courses to improve the formation of future engineer. The courses were offered along the five years of course distributed as follows: Philosophy in the first and second years; Assisted Training Period since the third year to the last one; Human Resources and Management Strategies in the third and fourth years; Development of Projects in the fifth year. The suggested distribution of the courses was conceived taking into account the considerable number of Basic Science, Basic Science of Engineering and specific courses of specific areas of engineering which were essential.

Electrical Engineering II – five years program, the curriculum was elaborated in a way that the students had before the beginning of the classes four weeks of intensive courses of calculus (to review and to learn what is necessary to have a good performance during the first year of the program), dissertation (to learn how to write reports) and scientific methodology (to learn how to use the scientific method and propose some hypothesis).

Besides the programs COPEC has implemented some other projects to foster the formation of the new engineering. They are projects designed to serve engineering students of any engineering school of the region. The objective is to offer opportunities for students to get better experiences and enrich their formation.

Civil Engineering Internship Project – It is a partnership of COPEC with Construction Companies of the region to provide proper internships for civil engineering students. It is offered to students of 4th and 5th years of civil engineering programs of any engineering school of the region. The student is hired as assistant and s/he has the opportunity to experiment all the phases of a construction site from the blue prints to the final touches of the building.

The Engineering Educator Graduation Program – The PEE Program offers two graduate degrees: the Master of Science and the Doctor of Philosophy. It is a very dynamic and rich program, developed in modules, following the trend of global formation of professionals, mainly to attend the need of a prepared engineering educator to act in the several different cultural environments, which mobility has imposed as a fact of life for researchers and teachers at graduation level. Not to mention the necessary new competencies of educators such as: evaluation management; development competencies; communication skills; teamwork; ethics and intercultural competencies. So this program has been designed to fulfill this lack of engineering educators.

The Port Engineering Program – The most recent one developed and implemented by COPEC's team, which is a program designed and implemented at Master of Science and the Doctor of Philosophy level very proper for the time and geographical region once there is the largest seaport of Latin America [08].

VII. Study Abroad

In Brazil: It is a project that brings to Brazil students from abroad in a program of 15 days (can be more or less) when they have academic, social and cultural activities. It is very intensive period when the students visit 5 of the 9 cities of Atlantic Forest Region at the sea shore of Sao Paulo state, as well as visit to different industries and universities.

Abroad: It is a project that brings students to USA and Sweden in a program of 15 days (can be more or less) when they have academic, social and cultural activities. It is flexible once it is designed in according to the group needs. It is a way to provide students a good international experience.

All the programs and projects of engineering education that were implemented showed that it is possible to innovate and change the formation of engineers and so to provide them the tools that they will use as professional and as researcher.

COPEC understands that the programs should provide the future engineers a generalist formation and to instigate the development some skills such as: communication, knowledge of foreign languages, environmental awareness, and ethics among others in order to be prepared to face the contemporary work market in a world of no borders so extremely competitive and challenging.

All the programs are customized and the students receive a diploma with hours that can be used as ECTs in their University of origin [09].

VIII. The Formation of the Engineer seen by COPEC

COPEC as an organization that works for the future of education has established some guide lines to be applied on the design of engineering programs. The guide lines are the result of researches as well experience designing and implementing engineering programs [10].

- The programs should be flexible;
- Have more practical activities;
- Internships as a way to provide real experience in engineering.

The formation of the engineer must consider above all the strong basis in basic sciences and basic sciences of engineering and the programs should instigate the students the willing to develop some skills such as showed bellow:

Basic Sciences

\+

Basic Sciences of Engineering

\+

- Aptitude to conduct and implement projects
- Responsibilities for actions and results
- Creativity and innovation potential
- Mastering technologies' evolution
- Positive attitudes and behaviors
- The willing to learn all life long
- International experience
- Entrepreneurship mind
- Respect to diversity
- Communication skills
- To work in teams
- Strong ethics.

These capabilities can be instigated in the students by means of new education proposals, exchanging programs, international experiences, double diplomas, internships, technological initiation and other feasible implementation at the engineering programs [11].

IX. Final Considerations

Education comprehend the process of teaching/learning that happens not only inside a classroom but in any opportunity when the knowledge (whatever it is), is transmitted from one source to a receptor. Real learning happens when the mind is capable to situate any information in a particular context and if possible, in the universe that it is inserted. The fragmentation of the complex world in separated pieces, breaks up the problems restraining the multi dimensional aspects and it has as result the decrease of the possibilities of comprehension and reflection, eliminating the opportunities of real learning. The science has developed itself in this kind of knowledge fragmentation, generating the super specialties, divorced from the global context that they are part, atrophying the ability of integrating and evaluating the issue in its context. There is a loss of long-term prognoses, which has a straight incidence in the decisions and choices, when they are necessary. The New World order demands a new kind of professional, capable to think global without loosing the dimension of local and vice-versa. It is not easy to form this kind of professional although it is known exactly what is needed.

The contemporary paradigm of education preaches among other requirements the international experience as one of the most important skills in the formation of the new engineer. The environmental consciousness, the willing to work in teams, and etc, it is a long list but the most important aspect of engineering formation is the strong knowledge of basic sciences and basic sciences of engineering because these are the tools that will enable the future engineer to perform successfully and more over it will give them the self confidence necessary to win.

For high education institutions the necessary changes are immediate. New ways and approaches to form the professional have to be implemented because the university is the institution responsible for the final product of the long educational system in any country. With weak or good pupils the mission is to prepare the engineers to work and make the world goes round using new technologies and promote the advancement of sciences.

Summarizing the formation of engineers should focus on the generalist formation and to stimulate in the students the capability to develop their creativity; to teach them how to use the information to improve their work as well as to commit with environment; and above all to adopt a strong ethics.

The majority of the programs developed by COPEC Team of education were implemented in different Universities in the region, which has 9 universities. At present moment COPEC has started its own Institute of Education starting with 3 different programs, one in Dentistry and 2 in engineering.

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Session 05F LiLa Special Session: Library of Labs - LILA Project

Deployment of Remote Experiments: The OnPReX course at the TU Berlin

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Federated authentication and authorization for reusable learning objects

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Nano-World A Showcase Suite for Technology-Enhanced Learning

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Generalization of an Active Electronic Notebook for Teaching Multiple Programming Languages

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Delievering authentic experiences for engineering students and professionals through e-labs

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Deployment of Remote Experiments

The OnPReX course at the TU Berlin

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Abstract—**The development of internet technologies leads to recent trends of online based education in universities. Remote experiments give the students the possibility to experience real physical situations and compare their experimental results with those of the physical models (simulation). Online learning based on remote experiments is capable of diminishing the scantiness in practical courses in the universities. In this work we present an online practical course based on Remote Experiments (OnPReX), interactive graphics and an online tutoring system organized at the Technische Universität Berlin. Furthermore we give background information about the development of our remote experiments. The remote experiments are real–life settings, designed and engineered at the solid-state physics department of the Technische Universität Berlin. We describe the development of two online practical courses, focusing on classical and modern physics, addressed at undergraduate engineering students. We ran the online practical course based on Remote Experiments in two test phases over two semesters and conducted an evaluation from which we improved technical and pedagogical aspects of the experiments and the course.**

Keywords- Remote experiments; online tutoring; online course; Physics in engineering education

I. INTRODUCTION

Learning by experimentation is a fundamental element in natural and engineering sciences. The involvement of science and engineering students in practical work is a fundamental precondition of understanding the concepts and processes of science. A practical course in undergraduate engineering and science studies requires large amounts of resources, equipment and manpower. Unfortunately many universities are not able to provide in engineering education the laboratory capacity for the numerous undergraduate students due to the high costs involved. At the Berlin Institute of Technology there are more than 500 students in an undergraduate physics course. In the learning process of physical phenomena elements of physics theory, physics models and practical experiments must be involved. Often theory, models and experiments are offered separately, with time shifts in the curriculum, leading to a discontinuity in the learning process. Also there is a set of physical experiments not included in physics curricula, because they have a unique or expensive setup (e.g. Raman spectroscopy). Some other experiments are too dangerous to be conducted by beginners (e.g. the experiments with radioactive sources). Due to the lack of possibilities to provide a practical course for these students we organized an online practical course based on Remote Experiments (OnPReX). Our Online practical course is a combination of the remote experiments with an e-learning software platform called Moodle [1]. Remote experiments are real-life settings, built up at the TU Berlin and connected to a PC. We named this setting Remote Farm [2]. These computers are also used as web servers, so everybody can get access to the experiments through a free browser plug-in and gain control over all devices. All data recorded during the experiment is stored online and is accessible for users. The course schedule can be explained briefly as following. After studying the fundamentals of physical phenomena the students perform the experiments in small groups with the help of available literature and an online tutoring system in an online learning platform (ISIS) [3]. The acquired data can be evaluated and analyzed with suitable data processing programs. The reports have to be sent for correction via email to a lecturing tutor (see II.B). The OnPReX participants have, due to the online character of OnPReX, the possibility to take part in the practical course at any time and anyplace. Khachadorian et al. [14] showed that the OnPReX course matches with the authentic online learning environment characteristics explained by Herrington et al. [5].

II. THE COURSE

Any effective learning process in science should be based on the theory, physical models and experiments. In general these three elements are offered in separate courses and consequently the learning process of theory and experiment lacks cohesion. The online practical course based on Remote experiments (OnPReX) offers the possibility to deal simultaneously with theory, experiments and also physical models producing deeper understanding of physics. The elective OnPReX is an optional course for bachelor and intermediate diploma students. The OnPReX course (see Figure 1) contains classical physics and modern physics parts. The duration for each of these courses is one semester and is offered by the Department of Solid-state Physics at the Berlin

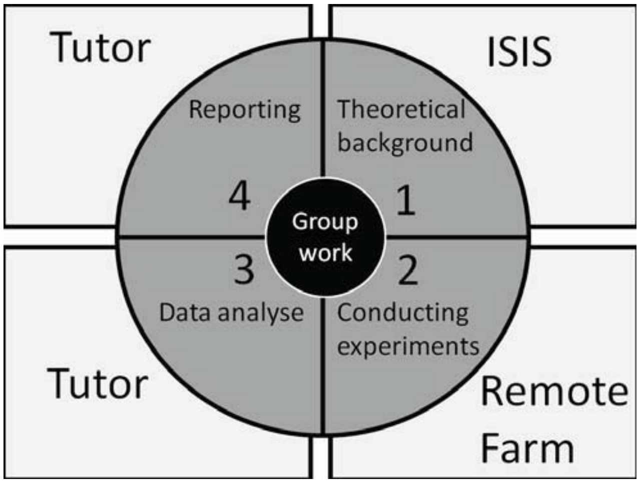

Figure 1. The four steps in OnPReX-course work flow are learning the theoretical background of experiments by information system for instructors and students (ISIS), conducting experiments via the web page of Remote Farm, data analysis with assistance of tutors and other work groups, and finally presenting the results of the experiment in form of a report

Institute of Technology. The OnPReX-course was tested over a period of two semesters, and it has been operational for one year in a regular setting. The participants of this course, which are mostly undergraduate engineering students, work in groups of three. Each group conducts six remote experiments (via the Remote Farm [2]), analyzes the data obtained from experiments and writes six reports. Additionally every participant must take an oral exam to get the three ECTS (European Credit Transfer System) points. These courses are a challenge in the organizational and managerial sense. We offer the engineering students the opportunity to work at the same time with the physical phenomena through self managed learning and by means of theory, physical models (simulation) and experiments (remote experiments), whereby similarities and differences between the theory, the simulated model and the experiment can be studied. This leads to a better understanding of a given physical phenomenon through the analysis from various perspectives. The participants of OnPReX gain the following skills and abilities, which are qualified as the general goals:

- Learning of the fundamental physical phenomena by experiments and simulations.
- Learn to deal with remote-controlled experiments and with practice-related problems during the experiment.
- Learn to deal with text-editing and data processing programs.
- Improving the skills related to the IT communications and online competence and their integration in team working.

In Section V we show by means of an evaluation if the general goals of OnPReX are achieved.

To manage the OnPReX-course we needed two tutor teams: the technical support team and the teaching tutor team:

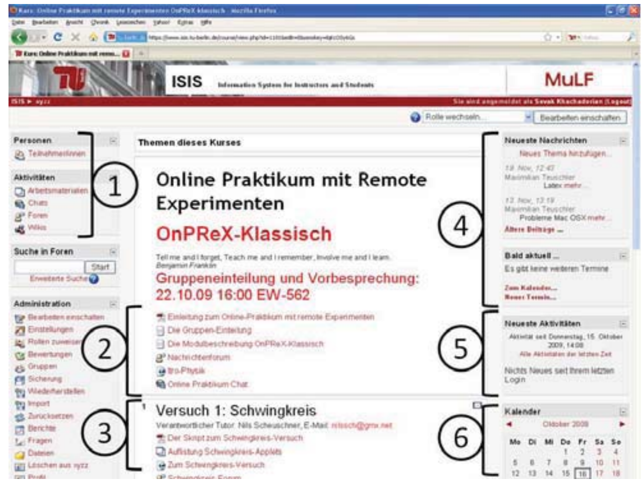

Figure 2. Information System for Instructors and Students (ISIS)-learning platform of OnPReX classical on the web page of TU Berlin. In OnPReX classical platform field showed with 1 to 6 are the list of participants, the general platform to the chats, forums and the wikis(1), general information about the course, the list of the participants groups, some organizational information and a forum and a chat room for the whole course (2), the field dedicated to first experiment explained in III.A.a) (3), the field for the coming appointments and latest news (4), latest activities field (5) and the course calendar (6).

A. Technical tutors team (Remote Farm):

The tutors of this team design build and program the experiment. The maintenance of existing experiments and debugging the technical problems are part of their duties. This team consists of three tutors and two of them deal with the programming and the electrical part of experiments and one of them deal with designing and building the mechanical setup of the experiments. This team is responsible for the activities in the Remote Farm and work under supervision of a team leader.

B. Teaching tutors team (ISIS platform):

This team consists of three tutors. Every tutor is responsible for two of the remote experiments. The teaching tutors provide support to the OnPReX participants, understand the theoretical background of the experiments, analyze the data, and write the reports. They also correct the reports and consult the students to solve the problems. These tutors must answer the student's questions in the forum regularly. This team works under supervision of the course instructor. The teaching tutors work in the ISIS environment.

III. THE COURSE CYCLE

The course cycle of OnPReX, as shown in Figure 1, contains four sections or four steps that the participants need to go through. The sections represent different learning activities: the first step focused on the theoretical background of the experiments using the Moodle [1] learning environment. Steo two is conducting experiments in the Remote Farm [2] via the Internet. Step three is the analysis of the obtained data in cooperation with the other group members and the tutors and step four is writing the scientific reports with the help of the tutors. We explain these processes below.

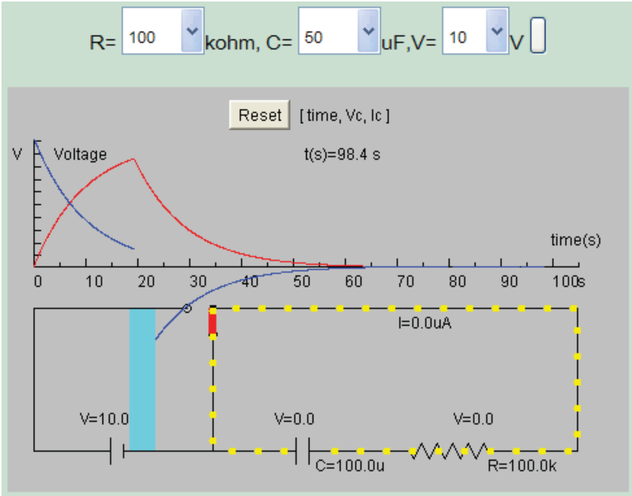

Figure 3. The simulation of a parallel plate capacitor taken from [4]

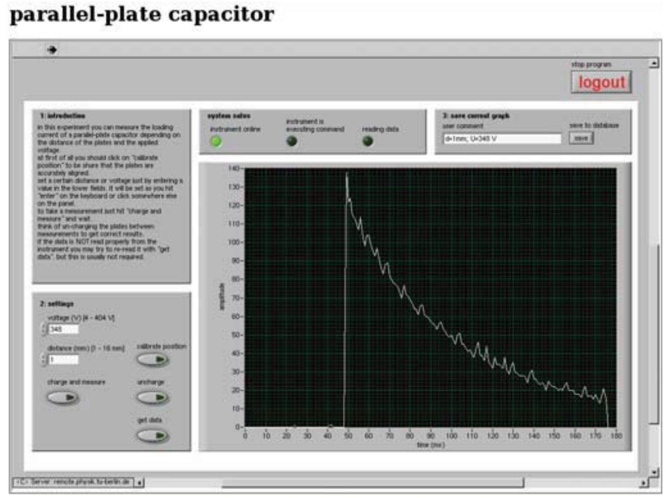

Figure 4. Front-panel of the Remote Experiment "parallel-plate capacitor". The graph shows the discharge curve of the capacitor for a given plate-distance.

A. Learning the theory: Step 1 in the course cycle

A well organized online course requires an efficient learning management system (LMS). We chose Moodle as our Virtual Learning Environment. The educational roots of Moodle as a learning management system is the "social constructionist pedagogy" [1]. Moodle is designed to help teachers create online courses with opportunities for improved interaction between students and tutors. The advantage of Moodle is that it is very flexible and can easily be deployed to thousands of students. Many institutions use it as their platform to conduct full online courses. Moodle offers series of activity modules such as announcements, course contents, documents, groups, project calendar, forums, wikis, databases to build richly collaborative communities of learning around their subject matter (in the social constructionist tradition). In Berlin we use a modified version of Moodle, called ISIS (Information System for Instructors and Students). The ISIS platform offers for each course an environment, where the whole course organized. We use two separate Moodle (ISIS) course environments, one for OnPReX classical and one for OnPReX modern. The ISIS environment in general on one hand due to its functionalities such as forums, wiki's and chat and on the other hand the various learning resources offer an efficient learning platform for the participants. The first step in the OnPReX course cycle is learning the theoretical background of remote experiments (see Figure 1). In Figure 2 we show the web page of ISIS for the OnPReX-modern physics. Each course management environment was divided into six parts. Every part, leading to a remote experiment contains the following learning resources and functionalities:

a) Learning resources:

The learning resources are listed for each remote experiment separately in the ISIS platform (see Figure 2). This includes the following elements.

- Script: a script contains the theoretical background of the experiment, the experimental setup, a guideline to conduct the experiment and the experimental tasks to be done. These scripts are an initial help for students and should facilitate the process of conducting experiments, data analyzing, and reporting.

- Simulation: Simulations of the remote experiment produce the same physical quantities for measurements as in real experiments. The theory, demonstration of similarities and differences between simulation and the experiment results in better understanding of the physics behind the experiments [11]. In Figure 3 we show a simulation related to discharging and charging behavior of a parallel plate capacitor [4]. The association of this simulation with the parallel plate capacitor remote experiment offered in the Remote Farm helps to understand the similarities and differences between simulation and real experiments.

- Remote experiment: The link from ISIS to the remote experiment. The remote experiment is the central point of the OnPReX. The course participants run the remote experiments through the web page of Remote Farm [2], which will be explained in Section III.B and IV.

b) Functionalities:

As shown in Figure 2 the ISIS platform of OnPReX classical [3] has some functionalities listed below.

- Forum: Each experiment has a separate forum, where participants discuss the experiment, its theoretical background and the experimental issues and problems. The questions and the comments can be edited and categorized every semester. The result of discussions can be also added to the wiki.

- Wiki: Every Experiment has a wiki page. This gives the participants the possibility to create and edit the contents and their gained know-how related to the experiment. With this functionality we aimed to provide the opportunity for participants to have a role not only as an user of learning resources but also as a content provider (a characteristic of the authentic learning environment [5]). These wikis should emerge as collections of learning resources and simulations and information about the theoretical background of experiments. The teaching tutors mentioned in Section II.B moderate the formation of the wikis in terms of categorization and sorting and also the editing of the contents provided by the students.

- Chat: Each experiment field has a chat room, where the student can chat about the experiments. We added this functionality to the ISIS page and motivated the students to use it and find out if this functionality is convenient for use in OnPReX. The evaluation of the course shows (see Section V) that this functionality is not used often by the participants. The participants of the course prefer to communicate via email, the forum or chat using other instant messaging services like Skype, Yahoo Messenger, etc.

B. Conducting experiments via Remote Farm: Step 2 in the course cycle

The second step in the course-cycle (see Figure 1) is conducting the experiments. The students use their web-browser (i.e. Firefox or Internet Explorer) to perform the experiments. The experiments of the Remote-Farm are real-life setups hosted at the TU Berlin. All variables can be manipulated via the server controlling the setup, which is realized by digital to analog converters, relays, stepping motors etc. For most of the experiments we also offer a video stream over the Internet to view the changes in the setup on-line. In Section IV we give a more detailed introduction to the implementation of our remote experiments. The control of the experiments, web-server and the browser plug-in are provided by a software called "LabView" [6] (by National Instruments). The plug-in is freely available over the Internet and is compatible with common operating systems (Windows, Mac and Linux) and browsers. So far the Remote-Farm offers 12 experiments with two additional setups in the construction-phase. One of the recently developed setups is the parallel-plate capacitor. In this experiment the students can study the discharging behavior of a capacitor with variable plate distance. Figure 4 shows the control-panel of this remote experiment. The setup of the experiment (shown in Figure 5) consists of two circular shaped aluminum plates with a diameter of 20 cm. The plates can be charged by applying voltages between 4 and 400 V. The capacity can be varied by changing the distance between the plates in a range of 1-16 mm. The students have to record discharging current curves, in order to determine the capacity for the given distance. The results can be compared to the theory studied in the first step of the course cycle or to related applets available on the Internet.

C. Data analysis: Step 3 in the course cycle

The ability of acquiring real experimental data is one of the many advantages of remote experiments. The ability to collect, analyze, and interpret data are the core-skills for scientists and engineers. Moreover, the engineers must learn to form and

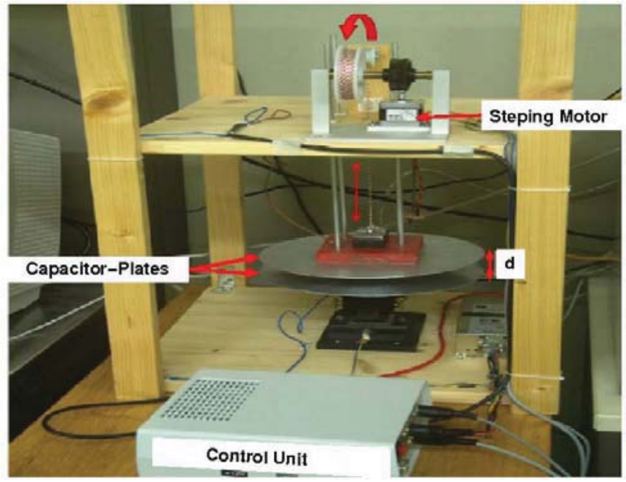

Figure 5. Photo of the parallel-plate capacitor. The circular plates are visible in the center of the image.

support conclusions and make order of magnitude, judgment and use measurement unit systems and conversions. This is important when reviewing experimental results and others work. Analyzing and representing the experimental results are one of the key skills taught in this course (see the OnPReX general goals in Section I). The measurement data must be evaluated and analyzed with the suitable data processing programs. The experimental data from the remote experiments are afflicted with experimental errors. The calculation of these errors, identifying unsuccessful outcomes due to faulty equipment, construction, process or designs are also skills that the students learn through OnPReX. To make the learning of "data analyzing basics" for OnPReX-participants easier we prepared an introductory script where the basics of data analysis and some data analyzing software products are introduced (see Section III.A.a)). As shown in Figure 1 (fourth step in the course cycle) we support the learning of data analyzing skills by online tutoring. As pointed out in Section II.B the teaching tutor team supports the OnPReX participants to solve the problems due to the data analyses. The OnPReX-participants exchange information and know-how among each other and also with the tutors via email, forum, chat and the wiki. The communication of the tutors and the students becomes easier through the ISIS Platform.

D. Reporting: Step 4 in the course cycle

The main purpose of writing scientific reports at universities is to communicate the results of experiments. The process of writing a scientific report also includes valuable practice in articulating the theoretical and empirical basis of a particular experiment, and the significance of the interpretation of results. With this training the undergraduate students are well prepared to produce reports for postgraduate studies and communicating their findings to the scientific/technical world. In an introductory script we give a general idea of the sections of scientific reports. The rest of this skill can be learned in the form of learning by doing with the assistance of tutors (teaching tutor team Section II.B).

IV. TECHNICAL DETAILS ON REMOTE-EXPERIMENTS

Our remote experiments are controlled with commercial software called LabView [6]. We currently use the version 8.20, which is not the newest version available. All devices manipulating parameters in our experiments are not directly connected to the server. For safety reasons we installed an additional microprocessor-board for each setup, which checks all critical parameters and is such able to prevent the setup from being damaged. The collection of data is in some cases performed by these micro-controller boards (connected to the server via RS 232), in other cases we use commercial meters controlled over RS232 or similar industrial standard interfaces. Examples for these meters are voltage, current, Geiger-Müller counter or charged coupled devices (CCD). A very important part of remote experiments is the ability to observe the experiment on live-pictures. To actually see the changes being made is one key learning experience. On the other hand, the live-pictures are the most important proof for the existence of real experiments. Most of the effects that can be studied with our experiments could be simulated by applets. We spent a considerable amount of time on the installation of a reliable video-system. After initial experiments with USB web-cams and software streaming solutions, we switched to commercial surveillance systems. The “AXIS 241Q Video Server” is a 4-channel video server providing Motion JPEG and MPEG-4 streams. It also provides JPEG still-images which we include in some of our LabView [6] front-panels, shown in Figure (control panel).

V. COURSE EVALUATION

The practical course with remote experiments is a relatively new type of course, which still needs improvement. There is proof that student evaluations are good indicators of effective teaching (see, [7] and [8]). The process of (a) gathering information about the impact of learning and of teaching practice on student learning, (b) analyzing and interpreting this information, and (c) responding to and acting on the results, is valuable for several reasons [9]. We present the outcome of the evaluation for the 2008 to 2009 winter-semester. In this evaluation the questions are divided in two categories. In the first category we tried to find out if the general goals of OnPReX are achieved and in the second category of questions we tried to get responses from the participants in order to further develop and improve the OnPReX course. We used online evaluation software (Unizensus) to evaluate the OnPReX courses [13]. Unizensus is an evaluation-software, which has been used in the Berlin Institute of Technology (Faculty of science) over years. We present the major results of the evaluation in Table 1. 91% of the interviewees have not passed any physics practical course before and 63.5% had no experience with writing a report. This shows that the participants were beginners and were short on experience due to physics practical course. 81% and 55% of interviewees believe that the OnPReX helped to improve their text editing, and data processing skills, respectively. 73% of the participants believe that their online competence ameliorated through OnPReX. 64% of the participants believe that the skill of dealing with remote experiments is "very important" for a future occupation as engineer. They believe that this skill has real world relevance. The fact that the remote experiments can be conducted at any time and any place is considered "very important" by 73% of the interviewees. Finally 82 % of the interviewees would recommend OnPReX to other students. From the results and the comments of the evaluation we also learned, that some of the remote experiments were unstable. The control panels of some other remote experiments were rated as user-unfriendly. On the basis of the feed back from the participants we developed some solutions and modifications e. g. reconfiguration of control-programs, exchange of live stream structure, designing more user-friendly control-panels for remote experiments. Remote experiments are advantageous especially where the experiment is dangerous for the experimenter. For example 37.5% of interviewees raise concerns over working directly with dangerous experiments such as radioactivity. 62.5% of interviewees prefer to work with the remote experiment over the real experiment since in the case of remote experiments no device-damage can be inflicted. We mentioned the OnPReX general goals before (Section I) and in the first category of questions listed in Table 1. We show that the general goals of OnPReX, namely the improvement of text editing skills, improvement of data processing skills and the learning of the standards of reporting are partly achieved. These results show that the OnPReX must further be developed to provide better conditions for the students improving their text editing (mean value: 2.7) and their data processing (mean value: 3) and reporting (mean value: 3) skills.

VI. ONPREX AND LILA

Lila (Library of Labs) [10] is a project co-funded by the e**Content***plus* program of the European Commission. The major goal of this project is the development of an integrated platform for remote experiments and virtual laboratories. Eight European universities are involved this project and three companies. The project partners share their remote experiments, virtual labs and the learning resources in the LiLa platform. The LiLa project aims to create a repository of remote and virtual laboratories and develop educational formats and supporting media to ease the use of the repository and guaranty smooth access by means of a retrieval and access control system. Any user with a Lila account can have access to the remote experiments in the Remote Farm and related resources. This platform provides an efficient framework for online collaboration between the users and the instructors of online courses in each partner university. Through the LiLa platform the users will be guided by the educational support system to use the database of learning content. By means of the integration of OnPReX resources in LiLa on one hand we will be able to offer the students a better and a more diverse collection of remote experiments, simulations and learning resources and also gain through the collaboration and cooperation with the other LiLa partners more technical and didactical know-how for further improvement of the OnPReX. In particular our benefits as instructors of OnPReX from the integration in LiLa will be to use the Lila platform as a central starting point for finding remote experiments and virtual labs with the intent to implement them in the OnPReX. Secondly, get didactical support using the educational format and supporting media of this platform and thirdly getting new ideas from the use cases in the LiLa platform.

TABLE I. THE RESULTS OF EVALUATION: THE QUESTIONS ARE DIVIDED IN TWO CATEGORIES. IN THE FIRST CATEGORY WE TRIED TO FIND OUT IF THE OBJECTIVES OF ONPREX ARE ACHIEVED AND IN SECOND CATEGORY OF QUESTION TRIED TO GET RESPONSES FROM THE PARTICIPANTS IN ORDER TO DEVELOP THE ONPREX COURSE FURTHER.

Nr.	Question[a] (objectives)	mean value
1	improvement of text the editing skills	2.7
2	improvement of data processing skills	3
3	learning the standards of reporting	2.6
4	the importance of dealing with remote experiments as engineer	2.3
	Question[a] (experiences)	
1	usefulness of introductory script	2.5
2	usefulness of simulation, animation and interactive graphics	2.2
3	user friendliness of Remote experiments	2.4

a. Rating scale: 1= Excellent, 2 = good, 3= satisfying, 4 = acceptable, 5 = poor

VII. CONCLUSION AND OUTLOOK

Presented was an online practical course with remote experiments for bachelor and intermediate diploma engineering students. We showed that the association of the remote experiments, online literature and simulation with an online tutoring system can result in an online practical course, which can be very useful in engineering education. We believe that the OnPReX can be very helpful for the engineering students through their academic studies and their career as an engineer. Clearly OnPReX support self managed online learning, as a valuable learning experience. Definitely we need to further develop OnPReX. Firstly the existing remote experiments need to become more stable and we need in parallel to design and build new experiments. Secondly we need to test the capacity of OnPReX concerning the number of participants to be served in a semester. In winter-semester of 2009 to 2010 we are aiming to offer the OnPReX as a compulsory subject choice for the students of "Natural Sciences in the Information Community". This is a bachelor course of studies where the students should pass during the first and second terms two physic practical courses with 12 ECTS points. We offer the students in the first term the OnPReX classical and modern course for 6 ECTS points. In the second term the students take the regular physics practical course offered by their faculty. Herewith we are going to test the capacity of OnPReX concerning the number of the participants. Further evaluation is needed to uncover if the OnPReX upgrades after the first evaluation were sufficient. We need to provide a simulation for every remote experiment to make the comparison of obtained data from remote experiments and simulation possible. Within the LiLa project we are aiming to get access to additional simulations and experiments in order to further improve the OnPReX course.

ACKNOWLEDGMENT

Authors thank S. Morgner for helping to organize the OnPReX.

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Federated authentication and authorization for reusable learning objects

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Abstract— **The LiLa (Library of Labs) project goal is to combine virtual laboratories and remote experiments spread out over Europe, which will be shared and exchanged among educational institutions in the form of reusable learning objects. This work addresses the needs of authentication and authorization when reusable learning objects are exported from an *experiment provider* organization to *an experiment user* Learning Management System. The paper discusses possible solutions based on using the SCORM run-time environment specification as a framework for learning objects and Shibboleth as a framework for a federated authentication and authorization.**

Keywords-virtual laboratories; remote experiments; authentication; authorization; learning objects

I. Introduction

The objective of the Lila project is to combine virtual laboratories and remote experiments (i.e. simulated experiments and experiments which are controlled remotely by computers) spread out over Europe, making them reachable in an environment with central retrieval and access facilitating synchronous collaboration and user generated production. The goal of this project is not only to integrate experiments and laboratories into a software infrastructure, but also to build a virtual portal in which experiments and laboratories are provided, including an on-line course system which guides users through experiments.

From the technical point of view, the LiLa portal is a repository of virtual laboratories and remote experiments on a central server, which will make it possible to include meta-data in laboratories and experiments to integrate them in library search engines and link-resolver technology. Basically, this means that virtual laboratories and remote experiments become learning objects, including learning object metadata as defined in [1]. A LiLa Learning Object (LLO) is then defined as a learning object with functionality and data elements which are specific to the access and use of virtual laboratories and remote experiments. The Lila portal gives access to these LLOs in an integrated environment, which includes a tutoring system for students and access to the 3D-engine Wonderland as a collaboration environment for students, teachers and researchers, providing users an organizational framework for online collaboration, for the transfer of virtual laboratories and connected support-services as well as for access opportunities to remote experiments.

In order to adequately exploit these learning resources, one of the objectives of the Lila project is to provide a well defined access control to laboratories and experiments. This work addresses the needs of authentication and authorization when reusable learning objects are exported from an *experiment provider*, that is, an experiment repository or a LMS (Learning Management System) of an institution providing access to resources for virtual laboratories or remote experiments, to an *experiment user* LMS, that is, the LMS of an institution which includes the learning objects as part of the curriculum for its students. In this context, the LiLa portal will act as a platform that will integrate different modules for laboratory and experiment searching, scheduling, authentication and authorization, and LLO importing and exporting. This paper discusses possible solutions based on the use of the SCORM [2] run-time environment specification as a framework for learning objects and Shibboleth [3] as a framework for a federated authentication and authorization.

II. Technology Overview

A. SCORM technology

Sharable Content Object Reference Model (SCORM) is a set of technical standards, specifications and guidelines designed to meet the functional requirements of the Advanced Distributed Learning (ADL) initiative. These standards are aimed at e-learning products like LMSs. SCORM is exclusively a technical standard, not pedagogical.

SCORM specifies that content should be packaged in a ZIP file and described in a XML file, named imsmanifest.xml (the "manifest file"). The XML file contains all the information the LMS needs to deliver the content, like information about how to launch each SCORM learning object (SCO) and, optionally, metadata that describes the course and its parts.

In LiLa, a LiLa Learning Object (LLO) is a SCO with additional constraints extended by additional metadata. Specifically, LLOs should obey the SCORM standard for learning objects, and are packaged in ZIP containers similar to regular SCOs. A LLOs is specific for one experiment or virtual laboratory, so a LLO will render a single web page, i.e, it will be a single (not composed) SCO with only a single href (html-file). Since most of the existing laboratories and experiments

This work was partly funded by the eContentPlus EU project ECP-2008-EDU-428037 'LiLa' (Library of Labs: Dissemination of Remote and Virtual Laboratories for Natural Sciences and Engineering).

use applets, a typical LLO will embed an applet providing access to the virtual laboratory or the remote experiment.

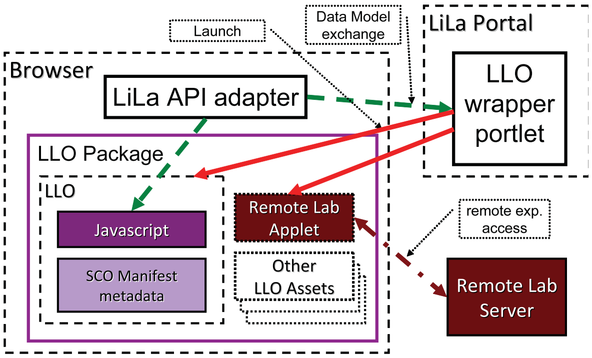

Figure 1. LiLa learning Object components

Fig. 1 shows the internal components of an LLO and the relations between an LLO, the LiLa Portal and a remote laboratory.

The LiLa portal will be based on portlet technology [4, 5], to take advantage of available functionalities such as collaboration, content management, groupware management, etc. On the other hand, there are no available portlets to display SCORM content. Having LLOs based on SCORM is important, because then it will be possible to deploy LLOs in all SCORM compliant LMSs. In LiLa a LLO wrapper portlet will be implemented to render the content that is uploaded to the portal as LLOs. This LLO wrapper portlet will be in charge of launching the LLO html page in the user browser, providing the adequate SCORM runtime environment – simplified, through the LiLa API adapter and of providing and launching the Remote Laboratory Applet, that in the case of remote experiments will have a client/server relationship with a remote Laboratory Server.

B. *Shibboleth*

The Shibboleth System is a standards-based, open source software package for web single sign-on across or within organizational boundaries. It allows sites to make informed authorization decisions for individual access of protected online resources in a privacy-preserving manner.

Shibboleth allows the deployment of a federated identity management system, in which the components of the identity management system are distributed across organizations, with each organization trusting the other to perform the functions of the components they host. There are two roles in this kind of systems: organizations providing identities, that would like to provide applications only the information required to make authorization decisions, and organizations providing applications or services, that would like to manage only the identity information required for their applications, reducing the risk of storing or accidentally releasing sensitive information they do not need.

The functional components of a Shibboleth implementation support these two roles. There is an identity provider (IdP) component, which has been implemented as a J2EE component, and a service provider (SP) that has been implemented as a C++ Apache module. There is also an optional "Where are you from?" (WAYF) service, that allows to redirect users to the right IdP.

The LiLa project has selected Shibboleth as the authentication and authorization technology for the virtual portal, due among other reasons to the wide deployment of Shibboleth in educational organizations in Europe. This will facilitate the creation of a federated identity management system comprising the organizations providing virtual laboratories and remote experiments and the LiLa project as the organization that will provide a repository for experiments and laboratories, enhancing their use by including services based on the inclusion of metadata (search and catalog creation), a tutoring system for students, and collaboration services including access to the 3D-engine Wonderland.

III. AUTHENTICATION AND AUTHORIZATION

A. *LiLa Authentication and Authorization Architecture*

Shibboleth is the authentication and authorization technology used in LiLa to control the access by registered users to the portal as well as to control the access to experiments and remote laboratories, contained in LLOs.

As regards authentication and access control, the general portal software architecture is shown in Fig. 2.

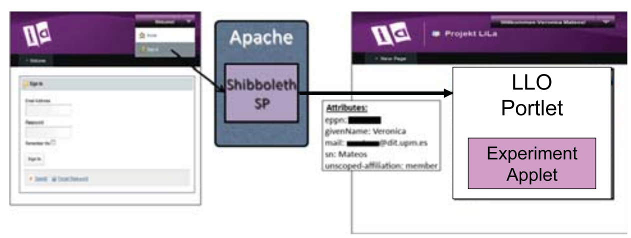

Figure 2. Shibboleth Authentication in the LiLa Portal

The general process is the following:

- A user goes to the home page of LiLa Portal. In this page the user can see some portlets.
- To access the LMS and experiments, the user has to log in the portal and go to LiLa Project page. Sign in functionality allows user to log in.
- User authentication is done using Shibboleth. As a result of the authentication process, the Shibboleth's Service Provider (SP) obtains a set of session attributes. These attributes are used to allow or deny user to access to protected resources. Also, the attributes could include information for authentication and authorization related to the LLOs which are rendered by using a portlet.
- If a user is shibboleth authenticated and she has the required permissions, she will go to the LiLa Project page, where she will see the portlets giving access to experiments and will be able to access them.

B. *Learning Object Authentication and Authorization*

The LiLa Portal is able to check the schedule and user permissions for experiments that are contained in a LLO as far as the LLO is launched in the LiLa Portal itself. However, downloading LLOs to a LMS would bypass the portal mechanism used to check the availability of a reservation for an experiment by a user. This section discusses the authentication and authorization mechanisms used in LiLa and possible solutions to overcome this problem.

The LiLa Portal uses Shibboleth for authentication and authorization, which for the purpose of the following description means that the portal will need to have a Shibboleth Service Provider installed, which will be in charge of redirecting the requests for AA to a Shibboleth Identity Provider, that can be located elsewhere.

One possible solution to “export” the LiLa authorization and scheduling infrastructure of experiments to other systems is to both a) integrate scheduling information and Shibboleth, and b) include some way of checking AA and scheduling information within a LLO.

Fig. 2 depicts the scenario in which Shibboleth is used to perform User Authentication and Authorization, while the authorization related to a LLO is carried out by a specific “Token based LLO Authorization Server” (TLAS).

A LLO includes some information or security token, the LLO AA Token, for example in the SCO Manifest *adlcp:datafromlms* data element. LiLa could update *adlcp:datafromlms* “on the fly”, if needed, when the LLO is downloaded to be included in an external LMS. A LLO is designed to get this information before launching the Remote Laboratory Applet, by retrieving the value *cmi.launch_data*.

Once the LLO AA Token is retrieved, the LLO will contact the TLAS using the token and in return, the TLAS will provide some piece of information which is needed to start the virtual experiment / remote laboratory applet. This piece of information will be passed as a parameter to the applet when launched. In the case of a remote laboratory applet, the parameter could be the url needed to contact the remote laboratory server, which might include authorization parameters depending on the level of integration of the remote laboratory with LiLa authorization and scheduling mechanisms. In the case of a virtual experiment, in which the applet is does not need access to a server, the parameter could be some access code needed to unlock the virtual experiment. The communication between the LLO and the TLAS will be based on AJAX, using the XMLHttpRequest object.

The task of the Token based LLO Authorization Server (TLAS) will be aided by Shibboleth. This server will be accessed through an Apache httpd server and protected by a Shibboleth Service Provider. This means that the TLAS will be able to perform the LLO authorization task using the user AA data provided by Shibboleth. This will make it possible to have an authorization schema where a LLO is only authorized if the user belongs to a certain organization that has obtained the access rights to the LLO. In this schema, the AA token includes information that links the LLO and the organization.

In the case of an experiment for which previous reservations are required, the TLAS could also be linked to the LiLa scheduling infrastructure, in order to only give access to the applet in case there is a valid reservation for the user. This would benefit remote laboratories that could use the LiLa reservation system even when the LLOs are used in external LMSs.

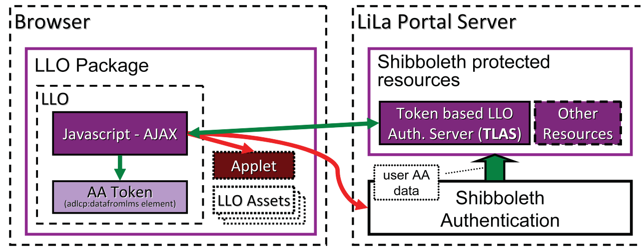

Figure 3. Authentication and Authorization for LiLa Learning Objects

Other alternatives have been considered. For example, AA attributes and scheduling information could be provided exclusively through Shibboleth. However, this would mean that in order to take advantage of remote laboratory reservations, external LMS would need to include a Shibboleth Service Provider.

Another alternative is to include the functions to check AA and scheduling status in the *LMSInitialize()* function that will be provided by the LiLa API Adapter in the LLO wrapper portlet. In this case, a LLO does not need to include any specific javascript code to perform the authentication and authorization, but when it is used in external SCORM compliant LMSs systems, no AA status check would be made unless the LMS own *LMSInitialize()* function is also modified. This could be an interesting alternative, since some of the most popular LMS are open source and LiLa could integrate the LLO AA and scheduling mechanism in LMSs such as ILIAS or Moodle.

IV. CONCLUSIONS

The paper discusses a solution for the authentication and authorization needs of learning objects used to access virtual laboratories and remote experiments in the context of the LiLa project.

The software architecture used in LiLa requires that the virtual laboratories and remote experiments are provided as LiLa Learning Objects (LLO), which are an special SCORM encapsulation including access control functionality for interacting with the Virtual Portal authentication components in order to force that the experiments are only executed by the adequate authorized students. The objective is to enforce access control to the experiments provided by LLOs not only when LLOs are deployed on the Virtual portal, but also when they are deployed on external LMSs, taking advantage of the functionalities offered by the Shibboleth system, that allows to build a federated authentication and authorization infrastructure for web applications.

The authors are currently working on implementation of the whole system that will help confirm the viability and expose possible problems of the proposed solution.

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Nano-World

A Showcase Suite for Technology-Enhanced Learning

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Abstract— **Over the past couple of years we have defined and implemented a variety of tools and instruments for supporting technology-enhanced teaching within the field of Nanoscience. Among others, the Nano-World showcase suite developed includes the following: a collaborative simulator for learning the basics of atomic force field microscopes; a remote laboratory which offers real-world access to experiments at the nanoscale level; software infrastructure for remote control and steering of ongoing experiments using mobile devices; interactive courseware that teaches the basic laws of physics such as force fields; a web-based platform for 3D visualizations of data collected via nano microscopes; and an interactive game for getting first impressions of atomic manipulations.**

In the paper we describe the different components and report on lessons learned from using the showcase within the university curriculum as well as an information medium for schools and public audiences. We also report on plans and first steps to interface the showcase suite with LiLa – the forthcoming library of labs.

Keywords: Remote Laboratory, Virtual Experiments, Nanoscience, 3D visualization, Collaborative Learning Environments

I. Introduction

In recent years, nanometer-scale science and technology has gained a lot of interest among researchers and the public. Boosted by the development of the scanning tunneling microscope (STM) [1] by Nobel laureates Gerd Binnig and Heinrich Rohrer at the IBM Zurich Research Laboratory, the fascination of investigating and manipulating material at the nanoscale level has attracted a large number of research groups.

At the level of atoms and molecules, we see a blurring of boundaries between classical disciplines such as physics, biology, and chemistry. Therefore, training in this new field is not only important for the different curricula involved, but is also a challenge due to its highly interdisciplinary nature. Future nanotechnologists need training in solid-state physics, molecular chemistry, analytical chemistry, and engineering.

The Virtual Nanoscience Laboratory of the University of Basel [2] consists of virtual and remote experiments, collaborative 3D visualization tools, interactive game-based learning methods, and an infrastructure that offers mobile access to remote and virtual experiments [3].

Hands-on examples, course materials, and simulations give an insight into the methods of Nanoscience and nanotechnology for undergraduate students of different disciplines.

II. Virtual Experiments: NanoSimulator

A. Content

With the STM as the first Nanoscience tool accessible to researchers, it was possible to make nanostructures visible that had previously been inaccessible to sensual perception. Nano tools also allow the investigation of additional physical properties such as normal and lateral forces or optical properties. All technical approaches are based on raster scan technology: line by line, a sensor rasterizes the surface and records information, very similar to a blind person who is scanning a text written in the Braille code.

Our NanoSimulator, a simulator for learning the basics of atomic force field microscopes, is based on five virtual experiments using the raster scanning method mentioned before. Experiments implemented include friction, electrochemistry, fluorescent dipoles, imaging technologies, and non-contact AFM on Si(111)7x7 surface [4]. As the friction module is the NanoSimulator experiment with the highest usage ratio, we have a closer look at it.

Friction is one of the oldest well-observed phenomena in the history of mankind. It appears in every technical application, whenever parts are in motion. Without friction we could not walk and no moving body would come to rest, for example. Recent research could prove that it is possible to move a weight over a surface without the dissipation of energy [5]. The virtual friction experiment (see Fig. 1) can simulate this recently explored behavior, as well as the well-known stick-slip behavior at the atomic scale.

The NanoSimulator allows the direct change of the specific parameters in every experiment. The simulator can be driven in collaborative mode: all students connected are able to simultaneously view any adaptation of parameters and the respective reaction of the simulation. By adjusting the scan size, for example, it is possible to zoom into a specific region. By increasing or decreasing the spring constant of the sensor, the contrast mechanisms can dramatically change, just like in the well-studied real experiments [6].

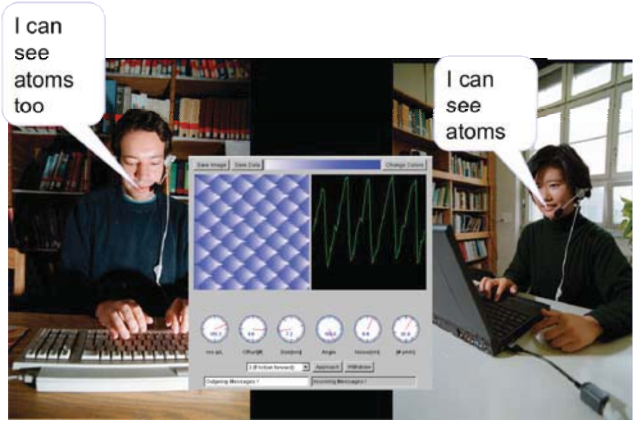

Figure 1. Friction mode of the nanosimulator. Two students observing stick-slip phenomena between a tip and an ultra flat NaCl surface. The simulation window contains several wheels for parameter settings as well as measurement results including visualizations.

B. Educational approach

All five virtual experiments follow a problem-based approach. Depending on individual skills, students get specific tasks or learning scenarios they have to fulfill using the simulator. They can act in the role of scientists and explore phenomena with virtual experiments in a similar way researchers did it a decade before in their top research environment.

The simulator makes simplifications of real-world effects, but it is close enough to practical usage. The friction mode of the NanoSimulator, for instance, allows the observation of atomic stick-slip phenomena [7] described by many researchers around the world. In addition, the NanoSimulator also correctly describes the recently investigated phenomenon of ultra-low friction [8].

Nanoscience experiments can be very expensive, which hinders their usage in education. By simulation instead, they become accessible at greatly reduced costs. Similar to aviation environments, Nanoscience students receive their basic training in a simulator context.

C. Technical aspects

All virtual experiments can run as Java stand-alone applications, Java applets or as client-server applications (Java servlets) for the collaborative mode. In the case where the actual simulation and the virtual experiment user interfaces are distributed over a network, the continuously calculated experiment data is streamed to all connected clients. Events exchanged between the client sites and the server ensure the synchronization of the application.

The virtual experiments are based on the open source virtual experiment framework vexp [9]. By using the modular and object-oriented vexp framework, new virtual experiments can easily be developed by extending the Simulator class.

D. Lessons learned

The planning, implementation, and testing of new virtual experiments are a time-consuming task. However, state-of-the-art languages such as Java have rich class libraries that support developers by providing solutions to generic problems like parameter exchange and data visualization.

Nanoscience students use simulators only if they are assigned specific tasks that they must complete and report on. In our setting, students that had to write a protocol to document their work have spent more time using the simulator.

III. Collaborative Web 2.0 Components: Nano3D

Nano3D is a collaborative Web 2.0 tool for the visualization of nanoscale measurements. It was developed to aid researchers in creating high-quality images and videos of their measurements (see Fig. 2) and to allow students to interactively explore atomic structures. The visualization of nanoscale worlds and the analysis of atoms and molecules offer scientists important new insights, since the function of an object is often determined by the fine details of its structure [10].

A. Content

An important goal of Nano3D was to provide researchers with a collaborative visualization platform. Nano3D allows users to easily create both individual and shared workspaces. In every workspace, they can handle the measurements uploaded, and access all visualizations previously created. The concept of easily accessible workspaces is also practical for the use of Nano3D in education. Students and pupils can be provided with a default workspace that already contains various measurements and visualizations. They can directly begin to explore the possibilities of visualizing measurements, without having to deal with importing measurements and setting up a work environment for their visualizations, as they would typically have to if they used a local installation of a visualization platform that is not web-based.

The measurements mentioned are essentially height maps of atomic surfaces created from data captured by a raster probe microscope. Various tools exist to create 3D representations of such height maps. POV-Ray [11] is a very popular tool, both because it is very powerful and freely available. Height maps can be imported and visualized from arbitrary points of view, allowing full freedom in the representation of the three-dimensional structure. However, POV-Ray is rather complex to use. The rendering of the scene is specified in the Turing-complete Scene Description Language. Text-based description of objects situated in three-dimensional space is not intuitive, and requires not only programming skills, but also good spatial sense. And even for researchers that have these abilities, creating visualizations with POV-Ray remains a time-consuming and problematic task. If not only still images, but movies should be created, additional knowledge about video encoding and publishing is required. Nano3D hides the complexities of the tool chain by using a set of flexible, parameter-oriented scene descriptions created by visualization experts. Users can control the parameters, such as viewpoint, coloring, scaling, light and orientation not via textual input, but through interactive components (HTML forms and Java applets) that allow an intuitive understanding. Selecting the viewpoint, for example, requires just clicking a point in a three-dimensional space; choosing height-dependent coloring is supported by selecting from a display of various color gradients.

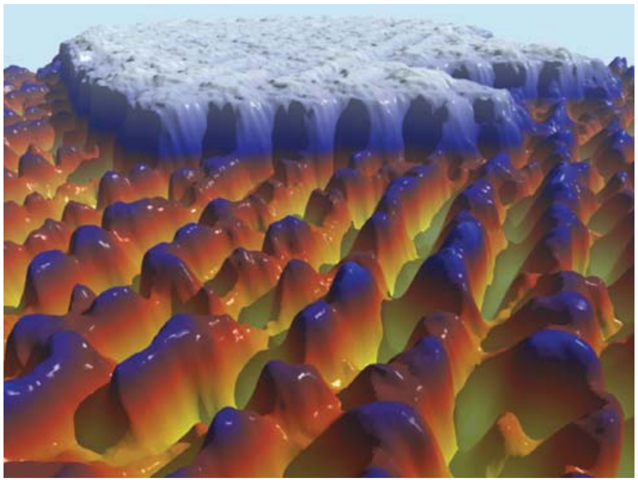

Figure 2. 3D visualization of a NaCl nano structure, created with Nano3D. The corrugations in the front represent individual atoms, the white plateau in the back is a mono-atomic ultra-flat terrace.

B. Educational approach

Nano3D allows students to work on real experiment data. However, they do not have to download and possibly preprocess this data, as they would have to if they used their own visualization solution. Real-world data is already available in the Nano3D workspace, and students can directly start exploring it through visualization.

By hiding the complexity of the tool chain necessary for creating visualizations, Nano3D allows students to focus on the cognitive impact of exploring scientific data through 3D visualization. Especially for undergraduate students whose technical skills are not that advanced, Nano3D offers the possibility to work with computer-based methods in the scientific process.

C. Technical aspects

Nano3D has two main components: a web front-end and a visualization back-end. The web front-end provides users with means to create their workspace and to upload their measurements (workspace organizer). Interactive components give the user intuitive aid in selecting appropriate parameters for the visualization. The user can edit the parameters and create and preview the respective visualization in an integrated view called render editor. The visualization back-end makes use of the ray tracer POV-Ray to generate renderings. Visualizations are created either as single images or as image sequences that are encoded into video using the open source video player MPlayer [12]. After the visualization has been created, a preview is displayed in the render editor, and the high-resolution image or movie is available for download in the workspace organizer.

Nano3D requires a Java Servlet container (we have used Apache Tomcat [13]) and an installation of POV-Ray and MPlayer (video support can also be disabled). The application has been successfully tested on Linux (Fedora Core 5) and Windows XP. The productive deployment of the application has been running on a Linux server for over two years.

D. Lessons learned

Nano3D is in productive use since January 2007, with a total uptime of 99.8%. The Linux-based server has been running for 626 days. The main users of the service were researchers and students from the University of Basel. However, statistics show that Nano3D has received regular traffic from several German universities. The German Museum in Munich has integrated Nano3D in its exhibition about Nano and Biotechnology [14].

Nano3D is included as a component in the curriculum of Nanoscience studies, where students can get a first impression of working on measurement visualization and exploration. It is also used in events addressed at pupils and prospective students. In research weeks for pupils organized by the Schweizer Jugend Forscht (SJF) foundation, Nano3D is used to help students understand the nano-scale world of modern physics.

Nano3D has also been used in science media communication. High-end visualizations have been produced for the University of Basel's research magazine UNI NOVA [15] and for the "Small is Great" brochure of the National Center of Competence in Research Nano [16].

IV. Interactive Insight Learning Elements: Nanojoystick

Undergraduate students of various fields making use of nano technology need a motivating but also simple introduction into the world of Nanoscience. Nanojoystick follows a game-based learning approach by offering a simplified simulation of a nano-scale environment. Users can move elementary building blocks of matter (molecules and atoms) and form new nano structures.

A. Content

Building new molecular structures atom by atom has been a strong wish in chemistry and physics for a long time. With the help of the new nano tools created in the last two decades, first steps in this direction have been taken. Notably, Wintjes et al. have demonstrated a nano-switch [17].

This recent development is brought to life in the Nanojoystick application. It allows students to directly manipulate a simulated atom-level environment.

Students control the movement of the tip of a scanning tunneling microscope in x and y direction via a joystick. In the virtual environment, they are given a nearly complete line of molecules. One molecule is displaced, and the task for the students is to fill the gap in the line by moving the displaced molecule with the tip.

Students can control the point of view, the movement of the microscope tip and the zoom level via the joystick. The joystick provides a very direct control that many of the students already know from computer games. The time required for completion of the task is measured, and a ranking listing the three fastest students is displayed. If several Nanojoystick stations are present in the same network, they exchange scores and create a network-wide ranking.

B. Educational approach

The game-based approach allows an intuitive first contact with the field of Nanoscience. However, the use of a joystick is motivated by the practice in the scientific community. Real scientific molecule manipulation experiments needs precise planning and must be performed very carefully. Joysticks provide the necessary high-precision user interface.

In the context of science communication events such as the Sciencedays in Germany [18], the Nanojoystick is an ideal demonstrator to invite scholars to get in touch with science (see Fig. 3). The use of several stations with competition through a global ranking is well suited to involve not only single, but small groups of visitors. The high-precision control of the tip via the joystick has been appealing to both girls and boys.

Figure 3. Youngsters making their first manipulation experiments at the nanoscale level. Three interconnected Nanojoystick stations were presented at the Sciencedays in Rust, Germany, attended by nearly 20.000 prospective students.

C. Technical aspects

Nanojoystick is a stand-alone 3D application that makes use of modern graphics processing unit capabilities. It is written in Java and uses the JMonkey Engine [19], an open source scene graph for Java. The engine provides an API for physics simulation, which provides the rule set for the Nanojoystick environment.

D. Lessons learned

A game-based approach to science is very attractive for young people. Experience from several public events, most notably the Sciencedays, has shown that the interest of youngsters in a complex subject can be initially stimulated by providing a playful entry.

Also, providing several stations and thus allowing small groups to concurrently experience the application has proven valuable. The addition of a networked ranking system additionally stimulates the interest of the visitors.

V. MOBILE E-LEARNING: NANOMOBILE

A. Content

NanoMobile is a system that uses mobile devices for monitoring and controlling scientific experiments. The experiments can be both real and simulated. The system is designed to take into account the limitations of mobile devices: it does not require much user input and the users do not have to read a lot of text. It is also easy to learn how to use the software through a common user interface applicable over a wide range of real experiments and simulations (see Fig. 4). Moreover, the system optimizes the data with respect to the client device properties such as screen size and sends the data to the client in a bandwidth-saving manner.

Complex scientific experiments can run for hours or days. Supervisors of the experiments may only need to take action or monitor the ongoing experiment every once in a while. Our system aids students and researchers in using their time efficiently. They are not required to stay in the lab during the entire experiment, but are still able to monitor and control the experiments. We see several advantages such as:

- Monitoring an experiment from anywhere, at any time. Researchers and students might not always have access to a desktop computer (they may leave the lab or even the campus), and under certain circumstances, it may be impractical to carry a laptop. PDAs and mobile phones, however, are usually available all the time and are always ready to use. This makes it possible to observe an experiment while users are on the move.
- Steering of remote experiments. When errors occur, users are not required to go back to the lab to solve the problem. They can use their mobile device to restart experiments, adjust the experiment parameters, and so on. This is especially useful for long-time experiments.
- Receiving instant notification from collaborators, tutors, and experts. Simple notifications can be sent by pressing a single button. Measurements can be shared with other users instantly and regardless of their location, given that they have the client application on their mobile phone.
- Self-tests and automated notification. After setting up an experiment, a user can focus on other tasks and only go back to the experiment when notified via email or SMS

that she needs to take action. Human supervision is only necessary in case of malfunction, extraordinary events or termination of the experiment. The mobile client and a notification system allow students and researchers to supervise their experiment in the most time-efficient manner.

Figure 4. NanoMobile remote steering interface on a PDA. Left: View of an observed surface with atomic resolution. Right: List of gauges to view and adjust experiment parameters.

B. Educational approach

We illustrate the educational approach of NanoMobile by describing several learning scenarios in which NanoMobile is used.

Scenario 1: Virtual experiments and mobile learning

We have stated that learning through virtual experiments is an important component of the Nanoscience curriculum. Many experiments take a long time to complete. If students are required to remain at the location where they have started the experiment, or if they only are able to access the running experiment when they are in proximity of suitable computing infrastructure, the motivation for persisting efforts in the virtual experiment suffers. If they are able to use their mobile devices to monitor experiment progress and take action when necessary, they can integrate the experiment supervision in whatever other activities they pursue during the day.

Scenario 2: Ad-hoc collaboration

NanoMobile allows ad-hoc collaboration in the context of an experiment. If a student conducting an experiment is unable to resolve an issue, she will typically require assistance from either a fellow student or from a tutor. NanoMobile enables instantaneous notification of other students or tutors via the clicking of a single button. The user notified can view the parameters and problems of the ongoing experiment on her mobile device and is able to directly resolve the issue. The ad-hoc nature of collaboration in NanoMobile makes involving fellow students and tutors in one's own learning effort much simpler and convenient.

C. Technical aspects

NanoMobile consists of client software for the PDA and server software that acts as a middleware between the client devices and the actual experiment.

The mobile client has four important modules. The monitoring module is responsible for visualizing measurement data. The command module allows the user to actually steer the remote experiment. The user can start, stop and pause the experiment as well as change the current experiment parameters. The notification module is a communication service that enables the user to inform other mobile users about the experiment. Several types of messages such as alert, special interest, or help requests can be sent to a specified list of receivers. Finally, the viewer module is used to toggle between views of attached web cameras. This module is of crucial importance, since it allows users to not only monitor a set of predefined parameters and conditions, but to actually see the ongoing experiment from various angles.

The four modules communicate with the experiment via the middleware layer. The middleware layer is implemented as a Java web application using the Java 2 Enterprise Edition (J2EE). The client and the middleware exchange messages via HTTP.

Clients request visualized measurement data via HTTP GET requests. To save expensive GPRS bandwidth, only the updated parts of the measurement data are sent. The measurement data in scanning type experiments (e.g.: scanning probe microscope experiments) is generated line by line. On stable network connections, there are many requests per unit time for very thin slices. This yields very good real-time visualization of the experiment. When the GPRS signal strength is bad, the delay between transmissions can be a few seconds. If the delay time is longer than the scan duration for the complete image (around 60 s), the client gets the image in one chunk.

A request contains several parameters such as start and stop line of the current slice, scaling factor and device type. Parameters are sent to the middleware as URL-encoded name-value pairs. Control commands for the experiment server are sent in the same way. The measurement data is received at the mobile client as an HTTP response. Image parameters and command responses from the experiment are included in the HTTP response as custom headers (e.g.: startline: 12, scanrange: 50). According to the image parameters (startline and stopline), the image slice is superposed to the image shown to the user. The user gets the impression of watching an evolving scan image as if she sat directly in front of the microscope.

The experiment continuously streams out raw measurement data on many channels. This image data flow can be as high as a few hundred kbps depending on the scan speed and the number of channels. As middleware and experiment server are usually located in the same LAN, only the transfer speed of the LAN connection sets a limit to the raw data stream.

To reduce the workload on the mobile client, only the data that the user wants to see at a given time is sent. To be able to react immediately to the demands of the user, it has to keep an up-to-date set of the uncompressed raw data matrix. The middleware component includes an image generator that creates raster images from the raw data (scaled to the client screen size). This ensures that measurement data is sent to the wireless client in a bandwidth- and transmission-cost-saving manner.

The J2EE technology provides scalability for the middleware layer to support many simultaneous clients. It also enables rapid implementation of an additional web application to control the experiment server. Web browsers of all computer platforms can display the HTML view of the servlet.

D. Lessons learned

Conducting experiments (be they virtual or real, in an educational or scientific context) has two important aspects: the required efforts can be sparsely distributed over time, and synchronous and asynchronous collaboration is often necessary. Obtaining information from and steering experiments not in situ, but from remote locations, is an important progress. By providing such remote control for ultra-mobile platforms, i.e. platforms that are always available to the user such as PDAs and smart phones, we achieve maximum efficiency in organizing experiment supervision and collaboration.

VI. Conclusion and Outlook

Our showcase demonstrates how the Nanoscience curriculum can be enriched through the use of advanced learning technologies. The simulation of experiments makes them much more accessible to students. Simulated experiments are much cheaper, can be repeated arbitrarily and require less prior knowledge than real experiments. Students can train under conditions that they will later experience in their real lab work.

Accessibility not only on a technical, but also on a conceptual level is facilitated through the use of advanced visualization and interaction techniques. Nano3D allows students and researchers to explore their measurements in three-dimensional representation. The high-end nature of the visualization makes Nano3D a valuable tool not only in exploration and interpretation, but also in publishing about the experiments. The Nanojoystick is focused more on prospective students and aims at providing a playful and intuitive access to the world of nanostructures. Experience from public events shows that the Nanojoystick is well suited for providing an interactive entry point for children in small groups. Finally, NanoMobile is a valuable tool for overcoming the restrictions that long-time experiments impose on collaboration and freedom of the supervisor. Through NanoMobile, students and scientists can monitor and control experiments collaboratively and completely independent of their location.

In a broader perspective, the most important feature of the Nano-World suite is virtualization. First, real-world experiments are virtualized in simulations. Second, the presence of users is virtualized through networked communication technologies. The result of the virtualization is a much broader availability of experimental and collaborative tools. An interesting challenge is the bringing together of the developed approaches in a single virtual space. This is the goal of the LiLa (Library of Labs) project [20].

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Generalization of an Active Electronic Notebook for Teaching Multiple Programming Languages

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Abstract **— In this paper we present a generalization of the active electronic notebook, OMNotebook, for handling multiple programming languages for educational purposes. OMNotebook can be an alternative or complementary tool to the traditional teaching method with lecturing and reading textbooks. Experience shows that using such an electronic book will lead to more engagement from the students. OMNotebook can contain technical computations and text, as well as graphics. Hence it is a suitable tool for teaching, experimentation, simulation, scripting, model documentation, storage, etc.**

OMNotebook is part of the open source platform OpenModelica. It is already used for the course material DrModelica in teaching the Modelica language but can easily be adapted to other programming languages which is also shown in this paper. The notebook can also be adapted to other areas, such as physics, chemistry, biology, biomechanics etc., where phenomena can be illustrated by dynamic simulations within the notebook.

The idea behind this paper is to show that by using a standardized interface the notebook can be extended to any computer language, i.e., being language independent. This is shown in the form of an implementation and adaptation of the notebook to support the Scheme language.

Keywords- OpenModelica, Scheme, DrModelica, Eletronic Notebook

I. INTRODUCTION

In this paper we introduce a research project for generalizing the modern object-oriented equation-based modeling and simulation environment OpenModelica towards also supporting other programming languages than Modelica, [1]. In this way the active student has a common platform for learning programming languages as well as given the opportunity to experiment with physical phenomena by using interactive electronic book, OMNotebook, [2].

This kind of interactive courses based on electronic books allows experimentation and dynamic simulation as well as execution of computer programs. The OMNotebook can contain program code, text, links, pictures, video, virtual and scientific visualizations. OMNotebook is an active electronic book that makes it is possible to integrating applied sciences in physics, human biology [3], mathematics and computer science.

This work was supported by the EU project Lila and by the ITEA2 OPENPROD project.

II. TECHNOLOGY

A. The Modelica Language

In the late 90th people from both the academic community and industry joined forces to define and standardize a multi-domain modeling language, Modelica, [1]. The object-oriented approach for modeling the dynamic behavior of engineering systems was adopted for Modelica, partly based of earlier prototype languages by the designers. In September 1997, version 1.0 of the Modelica Languagewas published on the web. Since then, the Modelica design group has had many meetings, resulting in new versions of the Modelica language.

The freely available Modelica Standard Library (MSL) contains many model components and examples from different application domains. Such components can be easily adopted by the modeler and integrated in his/her own application model. The inherent acasual capabilities built into the language lets the user express relationship between variables which gives more reusability compared to software based on assignment statements and related constructs as in conventional programming languages. A general type system including a general class construct unifies object-orientation, multiple inheritance, components/connectors, and templates/generics.

Furthermore, models in Modelica are described mathematically by Hybrid Differential, Algebraic Equations Equations (HDAEs). The hybrid is referring to the fact that both continuous-time and discrete-time models are handled, [4].

B. The OpenModelica Platform

In 2002 an initiative was taken by PELAB, [2], to develop an open source platform for the Modelica language based on more than 20 years of in-house experience of research in compiler construction. This effort was gradually expanded, and in 2007 an international consortium was formed to support the open source effort. Previously, the only option for the Modelica community, i.e., Modelica users, for simulating Modelica models was to use commercial tools.

The main goal for this open source platform is to create a complete environment for modeling, compiling and simulating Modelica models based on free software. Both the source code and the binaries are freely available and supported for a variety of intended uses in research, teaching as well as in industry.

The platform was originally written in a language called RML (Relational Meta Language), which is a popular formalism for compiler semantics. This formalism allows efficient compilation combined with optimized C code. This was later (2006) replaced by an extension to Modelica itself, MetaModelica, and the whole compiler was migrated to MetaModelica

The OpenModelica environment compiler translates the Modelica model into a flat Modelica code first and then into C code after a couple of more steps. Also an interactive command handler, i.e., a shell, for executing Modelica scripts and functions etc., is also provided in the environment.

The OpenModelica environment, shown in Fig. 1, consists of several interconnected subsystems. The debugger currently provides debugging of an extended algorithmic subset of Modelica, MetaModelica.

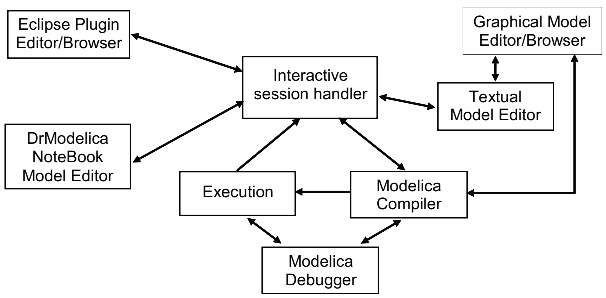

Fig. 1. Illustration of communication between different parts of the OpenModelica platform.

The interactive session handler interface is used in this paper for communication between the OMNotebook and the Scheme interpreter.

C. *OMNotebook – the Active Electronic Notebook*

The OpenModelica Notebook editor, OMNotebook, provides an active electronic notebook including an editor. The notebook is active in the sense that models inside the book can be changed and executed, it is not just a passive textbook or html page. This is one of the first open source efforts that makes it possible to create interactive books for educational purposes in general, and more specifically for teaching and learning programming. This functionality allows the usage of interactive hierarchical text documents where underlying chapters and sections can be represented and edited. OMNotebook supports functionality for Modelica model simulations, text, images and interactive linking between those. Furthermore, via the external interface, Scheme programs and other codes can be evaluated.

The notebook is currently being used for course material (DrModelica) in teaching the Modelica language and object-oriented modeling and simulation, (see Fig 2), but can easily be adapted to electronic books teaching other programming languages which is demonstrated in this paper. OMNotebook can also easily be used in other areas such as physics, biology chemistry, biomechanics etc., where phenomena can be illustrated by dynamic simulations within the book.

Traditional teaching methods with lecturing and reading a textbook are often too passive and don't engage the student. The option presented in this paper with an active notebook, however, facilitates the learning process, e.g. to run programs and exercises within the book, and mix lecturing with exercises and reading in the interactive book.

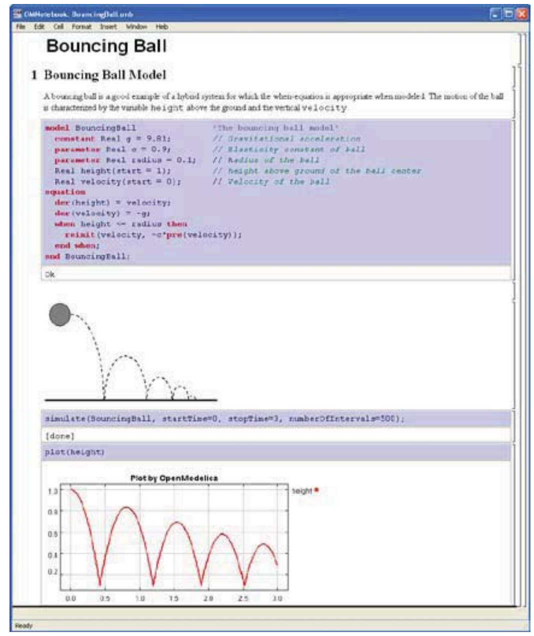

Fig. 2 Bouncing ball example with movement animation in OMNotebook

The hierarchical structure of traditional documents, e.g. books and reports, can also be applied to the notebook which means basically that the book is divided into sections, subsections, paragraphs, etc. This makes the navigation in the book sections easier.

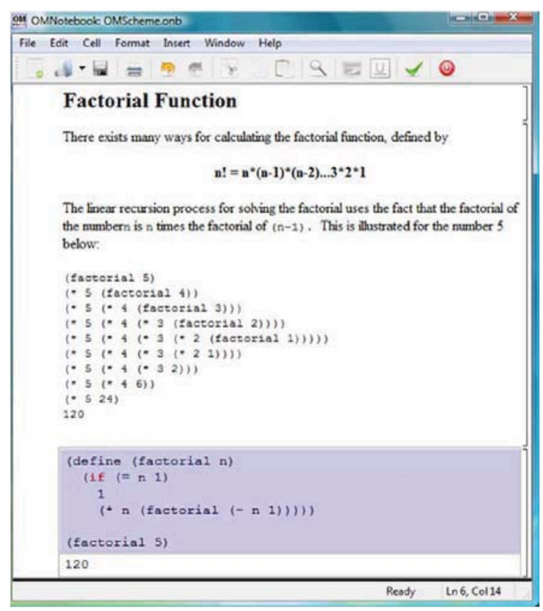

Fig. 3 Factorial function illustrated in OMScheme

In the OMScheme extension of the OpenModelica platform the interactive notebook has been further developed and adapted to the Lisp dialect, Scheme, for creating a suitable educational environment, where students don't have to focus on different tool and technology but instead focus on the information. An implementation of the factorial function using OMScheme is shown in Fig 3.

D. PLT DrScheme

The PLT Scheme is a dialect of the Scheme programming language, [5]. MzScheme is the interpreter behind the PLT Scheme for compiling syntactically valid programs into an internal bytecode representation before evaluation. The graphical user interface toolkit is named MrEd. DrScheme is an integrated development environment based on MzScheme, i.e., a MrEd application, with support for embedding third-party extensions. DrScheme provides developers with modular development tools, e.g. syntax or flow analyzers. The C API provided by this environment is embedded in OMNotebook and used in this paper for evaluating Scheme programs.

III. Conclusions

In this paper we outline the basic ideas of an active notebook for educational purpose intended for handling multiple programming languages. An early prototype is being developed for the Lisp dialect Scheme. This interactive E-book, OMNotebook, has been used successfully in both graduate and workshop courses for the Modelica language. OMScheme takes this idea further, combining an additional programming language with innovative teaching concepts.

Acknowledgment

This work was supported by the EU project Lila and the ITEA2 OPENPROD project.

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Delivering authentic experiences for engineering students and professionals through e-labs

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Abstract— **Use of leading industrial technology in 'remote experiments' and 'virtual laboratories' delivers authentic experiences to engineering students. Both types of learning resources can easily be shared between universities or industrial partners, leading to dramatic reductions in the costs associated with development, construction, operation and maintenance of traditional laboratory set-ups; however, each is characterised by inherent advantages and disadvantages. We compare and contrast remote experiments and virtual labs, using two case studies: 'Cambridge Weblab', a remote experiment built by the Computational Modeling (CoMo) Group at the University of Cambridge and 'SRM web-suite', a virtual lab developed by CMCL innovations. The Cambridge Weblab remote experiment uses a Siemens SIMATIC PS7 industrial interface to control a chemical reactor, yielding authentic experiences of industrial practices for students. A variety of pedagogical approaches employed by institutions using the Weblab are also discussed in this paper. The SRM web-suite uses an advanced engine design tool that simulates fuels, combustion and emissions in conventional and advanced internal combustion engines. The detailed simulations have been precisely tailored for training and educational settings. The web-suite labs provide students and engineering professionals with experience using the latest industry-standard technology, whilst supporting a wide range of educational goals e.g. undergraduate courses in combustion engines or chemical reaction engineering and advanced courses in futuristic fuels or powertrain engineering. We also assess the potential impact of these learning resources within the pan-European Library of Labs (LiLa) framework. Ultimately, we demonstrate that remote experiments and virtual laboratories are complementary, that there is significant potential for future integration of the two technologies, and that both can benefit from the latest industrial technologies.**

Keywords- Library of Labs (LiLa); remote experiments; virtual laboratories; chemical process control; advanced combustion engines

I. INTRODUCTION

A. What are e-labs?

This article compares three types of laboratory setups: conventional laboratories, remote experiments, and virtual laboratories. In a conventional laboratory, students are physically present in the laboratory, interacting directly with laboratory equipment and communicating face-to-face with classmates and instructors. In contrast, a remote experiment is performed on physical equipment housed in a laboratory, but is controlled by the student remotely, typically communicating with the laboratory equipment across the Internet. The software interface providing the controls of the remote experiment may be custom built [1, 2] or designed using a number of commercially available solutions [3, 4, 5, 6, 7]. Finally, virtual laboratories simulate the physical phenomena of a laboratory setup with a software on a computer and do not make use of any laboratory equipment. Students perform virtual experiments by interacting with the control interface of the software and observing the simulated results. Collectively, remote experiments and virtual laboratories will be referred to as e-labs throughout this article. The e-labs concept has also been discussed at several conferences dedicated to the subject, such as REV and ASEE/IEEE frontiers in education.

B. The Need for e-labs

E-labs are a well established resource for learning and are now becoming widely adopted [1]. The University of Cambridge WebLabs [8], CMCL SRM web-suite, MIT iLabs [9], TU Berlin Remote Farm [10], University of Stuttgart VideoEasel [10], and University of Basel NanoWorld [11] are examples of the e-lab learning materials presently available. There are many factors motivating the rise of e-labs including concerns over the cost, space, and staff requirements for conventional labs, as well as health and safety risks. Using e-labs can enrich curricula by providing students with experiences that would be too hazardous or prohibitively expensive in a conventional setup. Furthermore, simulations can use unique visualizations to provide insight not available in conventional labs; this is particularly the case for phenomena that are not directly observable. For example, the "Falling Coil" simulation at MIT [12] allows students to see changing magnetic fields and current as a ring falls towards a magnet, thereby illustrating Faraday's and Lenz's laws.

C. E-labs vs Conventional Labs

Below we present a comparison of e-labs and conventional labs by examining a remote experiment case-study and a virtual laboratory case-study. We propose that conventional labs, remote experiments, and virtual laboratories can all be important assets in curricula; viewing these methodologies as complementary, we identify suitable applications of each. Previous research has demonstrated that e-labs can be equally effective as conventional labs, in terms of understanding of course material, and that students do not express a strong preference for conventional labs, sometimes preferring e-labs as scheduling and time constraints can be alleviated [13].

Some key issues in the debate about e-labs versus conventional labs are: collaboration, analysis of experimental data, learning by trial-and-error, guidance from instructors, familiarity with laboratory equipment, and authenticity of experience [13]. The resolution of these questions is a matter of implementation, with a few exceptions. For example, both e- and conventional-labs can support collaboration, with e-labs using text, voice, and even video to link students. The same tools allow instructors to provide guidance and assistance during e-labs. Students gain experience working with experimental data through both remote experiments and conventional laboratories, but not with virtual labs. Whether learning by trial-and-error is supported can vary across all three types of lab. In conventional labs, time, costs, and safety concerns are all constraints; in e-labs the parameterization of the interface may be a limiting factor.

In some subject areas, only conventional labs can provide "genuine" experience with laboratory equipment and practice, so some conventional laboratories must remain in the curriculum. This is particularly the case for labs that involve a kinesthetic element and require the development of specific motor skills to ensure success; where this is not the case, a high quality interface, simulating the controls on laboratory equipment, can do a great deal to enhance a student's feeling of immersion in the lab and familiarity with laboratory equipment [2].

Finally, the authenticity of a lab is significant in preparing students for industry, motivating theoretical learning, and promoting student engagement. All three types of labs can provide an authentic experience as illustrated by the case studies below. The SRM web-suite case study demonstrates that a virtual laboratory can provide an authentic experience, an observation that, to our knowledge, has not been demonstrated previously.

II. THE CAMBRIDGE WEBLABS

A. Background

The Cambridge WebLabs were set up using funding and support from the 'Cambridge-MIT Institute' initiative which was carried out between 2000 and 2006. During the development of the 'iLabs' network [9] between 1999 and 2006, the Massachusetts Institute of Technology (MIT) obtained significant experience in using remote experiments for practical teaching of Engineering and Physical Sciences subjects. The Weblabs project itself started in 2003 after a Cambridge student who had visited MIT suggested that the Department of Chemical Engineering at Cambridge should develop remote experiments of its own. Within two years, Cambridge had developed an advanced remotely operated apparatus for teaching of Chemical Engineering and was exchanging usage of its new facility for usage of similar apparatus at MIT [14]. The apparatus has since been utilised successfully by a number of institutions within the UK.

B. Laboratory Setup

The Cambridge WebLabs teaching rig (Fig. 1) consists of a stirred reaction vessel with three pumped feed lines and an adjustable outlet overflow. The feed pumps and stirrer are controlled by a SIMATIC™ PCS7 interface (Fig. 2), which was donated together with the control software and hardware by Siemens Automation and Drives. The Siemens software and hardware is extensively used within industry and was chosen to help deliver an authentic educational experience.

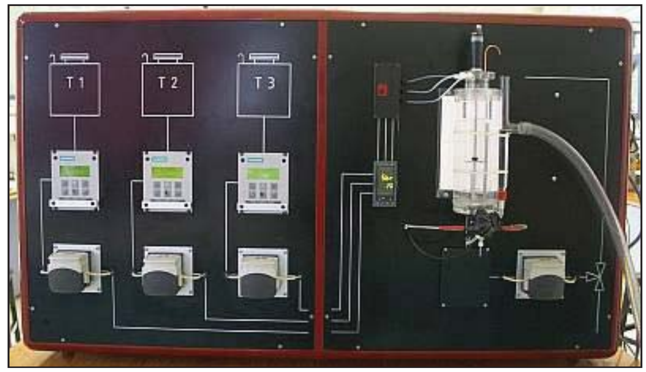

Figure 1. Hardware used in the Cambridge WebLabs

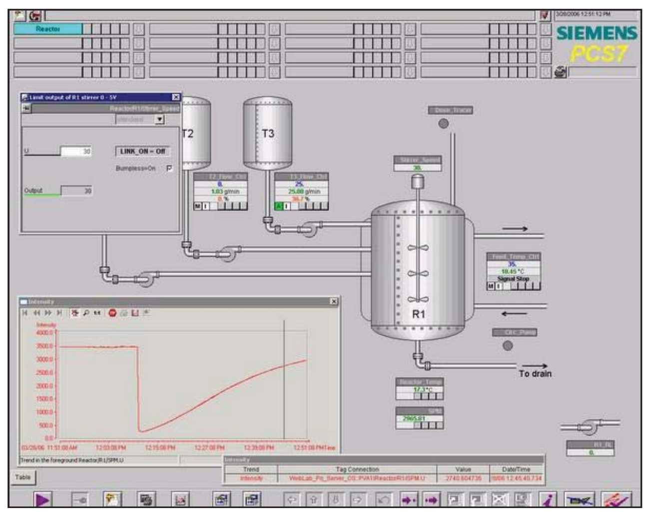

Figure 2. The SIMATIC™ PCS7 interface

So far, two WebLabs experiments have been developed: one on chemical reaction engineering and one on process control. The reaction WebLab was developed by Cambridge alone, but the control WebLab was developed as a result of collaboration with the Chemical Engineering department at Imperial College, London. Both experiments make use of the slow equilibrium reaction between aqueous phenolphthalein and hydroxide ions which is observed at high pH and results in increased or reduced intensity of the characteristic pink color of the solution:

$$\underset{\text{(pink)}}{PHEN^{2-} + OH^-} \underset{r_2}{\overset{r_1}{\rightleftharpoons}} \underset{\text{(colorless)}}{PHENOH^{3-}}$$

The intensity of the color of the solution is monitored by a photospectrometer and the readings can either be used diagnostically in the reaction experiment or for control purposes in the control experiment.

C. *Usage*

Since 2006, the WebLabs have been an assessed part of the Chemical Engineering course at Cambridge. In the case of the reaction engineering WebLab, students are required to complete a series of challenging theoretical exercises before they are permitted to use the apparatus. The exercises are designed to provide direction and focus to the experiment so that students can see their predictions tested and validated by following a rigorous procedure. In the process control WebLab, the preparation exercises are much simpler and students are given the freedom to try out a wide range of control parameters. The two experiments therefore use two very different pedagogical models.

So far, the WebLabs have been adopted in undergraduate teaching at the UK universities of Birmingham, Newcastle, and Surrey and Imperial College, London. The collaborating institutions have generally made use of the same supporting material and exercises as Cambridge.

D. *Student & Institution Feedback*

Student feedback on the Cambridge WebLabs (Figs. 3-6) has generally been good. The data in Figs. 3 & 4 use the Likert scale (1 = strongly disagree, 7 = strongly agree) and were collected for the class of 2008/2009. Most students responded that the WebLabs met their educational learning objectives and that they were a beneficial learning experience. However, the WebLabs proved less successful in capturing students' imaginations, as most users did not find either exercise significantly more (or less) enjoyable than other course work at a similar level. When used at other institutions, feedback on the WebLabs was mixed; in those cases, some students struggled to complete the preparatory exercises, which are tailored specifically to the Cambridge course.

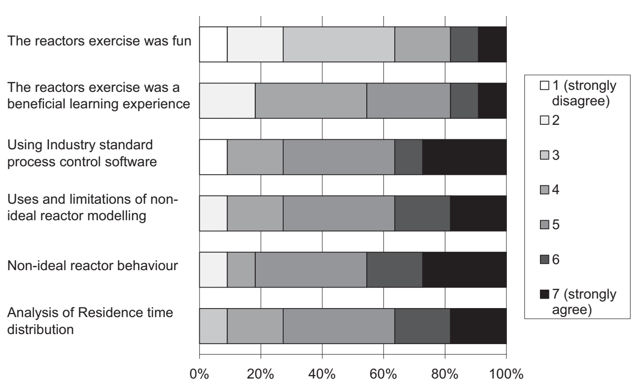

Figure 3. Feedback from the reaction engineering exercise

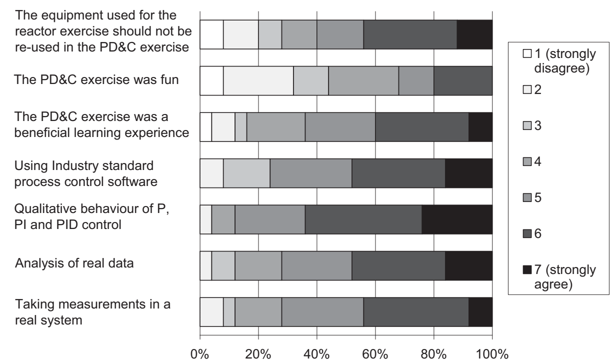

Figure 4. Feedback from the process control exercise

E. *Sustainability*

The concept of online learning through remote experiments has been demonstrated to be technically viable, but experience running the WebLabs at Cambridge has highlighted that the following problems need to be mitigated to ensure their sustainability:

- Unlike virtual laboratories, remote experiments have significant maintenance costs.
- It can be difficult for other institutions to use remote experiments as coursework exercises because it costs time and money to integrate them into their curricula.
- Universities' teaching times often coincide, meaning that only a small number of institutions can use a given remote experiment as part of their undergraduate course; the fact that only one user group can operate the experiment at a time is a significant limitation.
- Although interested in using each others' remote experiments, institutions may initially be unwilling to pay for that use, because e-labs are not yet a well established component of coursework.

Remote experiments are therefore most likely to be adopted by sharing facilities between a number of institutions that have the resources to develop them. It is also desirable to build experiments which have value for industrial research or testing, as rental of facilities to companies during universities' holiday periods could play a major role in ensuring sustainability.

III. The SRM Web-Suite Virtual Laboratories

A. *CMCL Virtual Laboratory Methodology*

The SRM web-suite is a series of virtual laboratories, developed by CMCL innovations, that focuses on combustion in engines, enabling insight into state-of-the-art combustion processes and futuristic fuels. The key innovation of the CMCL methodology for virtual laboratories is its basis of virtual labs for education using industry-standard research and development (R&D) tools. The simulations in the SRM web-suite use the same technology as CMCL's SRM suite [15], which has been adopted by R&D teams at engine manufacturers in order to improve engine performance and emissions and streamline the development process by reducing the number of costly experiments performed.

The SRM web-suite represents a new development in e-learning tools by being simulation-based yet providing students with an authentic experience. Simulations for virtual laboratories are usually developed strictly as educational tools, simplifying many details to ease the implementation or emulating simple experiments that students could have carried out in a conventional lab. Thus, the authenticity of a student's experience is sometimes diminished through the use of a virtual laboratory. In contrast, the SRM web-suite offers students experience with real industrial tools used in combustion, emissions, and engine development research. Moreover, the SRM web-suite provides students with the opportunity to perform experiments that would be otherwise inaccessible due to the safety, cost, and time constraints associated with an equivalent conventional lab. For instance, studying the characteristics of an unstable engine mode such as "knocking" in a conventional engine lab set up can be potentially hazardous because of the possibility of severe engine damage. The same phenomenon can be studied in a cost-effective and safe manner using the SRM web-suite.

B. *Technical Architecture of the SRM web-suite*

The architecture of the SRM web-suite is based on a client-server model in which simulations run on a remote server, either one of CMCL's servers or a licensed server deployed at an academic institution. Students then interact with a lightweight web-interface implemented as a Rich Internet Application (RIA). The only requirement for a student's system is a Javascript enabled web-browser, allowing any platform to be used, including mobile devices. This flexibility and convenience may encourage students to make more use of any optional laboratory components in a course. For example, enthusiastic students could entertain and educate themselves by carrying out SRM web-suite labs using their smartphones, whilst waiting for a bus. The client server-architecture and lightweight RIA interface allow new customized interfaces to be deployed easily to support new educational modules, while employing the same underlying simulation technology. This means that a larger portion of development time can be spent creating valuable supporting materials, rather than being consumed by technical developments.

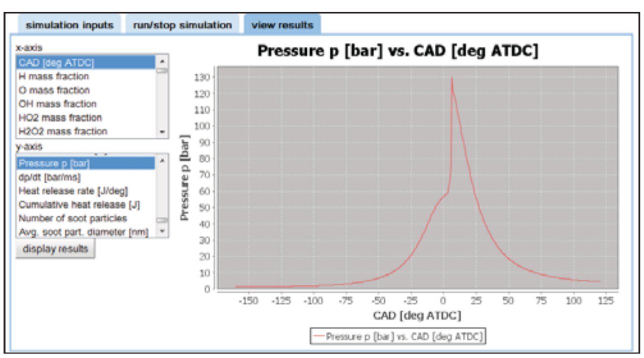

Figure 5. Screenshot showing simulation data from a web-suite laboratory

C. *Pedagogical Methods*

The methodology and architecture described in the previous section provide the SRM web-suite virtual laboratories with a flexible structure that can accommodate a range of pedagogical models and educational goals. The same simulation technology, provided with different user interfaces, can be used to teach introductory undergraduate courses on combustion engines and advanced seminars on future fuels.

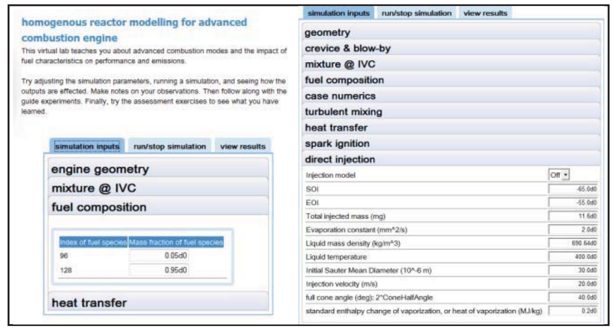

Figure 6. Web-suite interfaces for an introductory lab (left) and an advanced lab (right)

One key feature of the SRM web-suite virtual laboratories is that students can learn by trial-and-error, using the "productive failure" pedagogical method. Recent research has demonstrated that students retain a significantly higher portion of content using this methodology [16,17,18,19,20] in which they are first posed with an undirected task that they *attempt* to solve through experimentation and observation, followed by periods of increasingly guided learning during which their success rate increases. The web-suite labs enable a productive failures methodology to be used because there is no limitation on the number of times a student can run the simulation and no significant growth in cost with the increasing number of runs.

In the case of a conventional or remote experiment, there is often a cost (in materials and/or manpower) associated with each time the experiment is run; this requires that limits be placed on the extent to which trial-and-error learning can be employed. For example, each run of an experiment on the Cambridge WebLabs reactor uses chemical supplies which must be purchased and maintained by laboratory staff. Scheduling also constrains the use of trial-and-error learning in conventional and remote experiments, because access to laboratory equipment, whether direct or remote, must be shared between students. This is not the case with the SRM web-suite virtual labs, since students can perform the experiment at their convenience, repeating it as many times as they need, and any number of students can be performing the experiment simultaneously (up to the limitations of the server running the simulations). The ability to repeat experiments or perform them at a slower pace may also benefit students with different learning styles or rates.

In addition to use in a productive-failure framework, the SRM web-suite virtual laboratories are also ideally suited to more traditional guided methodology, or for demonstrative purposes as a part of lectures. The client interface can be augmented with guided interactive support at various levels, to provide additional information or to take the student through an experiment step-by-step. The design of the client interfaces for the web-suite labs makes it easy to embed them into larger modules and to incorporate a range of supporting materials such as videos, diagrams, and assessment exercises.

Finally, the SRM web-suite can be used for collaborative student work; however, collaboration tools are not currently a core feature in the virtual laboratories. Collaboration features are being included as part of the European Commission's Libray of Labs (LiLa) portal through which the SRM web-suite can be accessed, as described in Section IV.

IV. Remote Experiments or Virtual Laboratories – or Both?

A. Pedagogy

The pedagogy which is usually associated with remote experiments is very different from that associated with virtual laboratories. In remote experiments, students are usually required to follow strict procedures in order to complete an experiment safely and on time. This promotes strong organizational skills, can be used to enable team working skills, and helps to develop students' intuitive understanding of the physical world through interaction with the equipment. Virtual experiments have few constraints with regard to time and safety, and are well suited to an exploratory style of learning, which teaches fundamental concepts and improves theoretical understanding. Nevertheless, more advanced virtual laboratories, such as the SRM web-suite, can offer a good compromise between remote experiments and historical virtual laboratories. They require significant computing power, so run times are not insignificant, but are highly realistic in terms of the data generated and their relevance to industry. This means that they have many pedagogical similarities with remote experiments or real laboratories.

B. User Experience

It has been argued by some [13] that for many applications, remote experiments can provide learning outcomes which are of equivalent value to conventional laboratories. Others [2] broadly agree with this conclusion, but would insist that a balanced approach is still valuable as simple hands-on experiments can allow better collaboration and interaction with the equipment. They would nevertheless advocate remote operation if there are compelling pragmatic reasons (see section IV-C).

Student feedback from the Cambridge WebLabs suggests that the typical user is indifferent to remote experiments in terms of their enjoyment, although they are usually satisfied with the learning outcomes that they deliver; the findings of [13] would support this conclusion. It must also be stressed that the usage of an industrial interface was generally appreciated by the users of the Cambridge WebLabs and to some extent mitigated the students' negative views.

According to an old view which is perhaps becoming outdated, virtual laboratories are much easier to package in an attractive and exciting user interface which promotes user engagement, however their lack of relevance to the physical or commercial world limits their value as a learning tool for higher education. The next generation of virtual laboratories (e.g. the SRM web-suite) is designed to address these weaknesses by aiming for a higher overall level of authenticity.

C. Technical requirements & Sustainability

Virtual laboratories offer a major advantage over remote experiments in that their design costs are lower and that their maintenance costs are almost non-existent. By contrast remote experiments can be relatively expensive to set up, even when resources are shared between institutions, and maintenance costs are significant and ongoing. Furthermore, remote experiments are much more likely to experience 'downtime' than virtual laboratories. Virtual laboratories are therefore inherently more sustainable than remote experiments.

In the case of experiments which involve sophisticated equipment and are a standard part of a taught course, there is are strong pragmatic reasons why universities may wish to pool resources by using remote operation. As well as reducing costs, this reduces the risk that equipment will be left in a poor state of repair, thus allowing students to focus on the scientific aspects of their experimental work.

D. Usage & Integration into Curricula

It has been suggested [10] that there are significant benefits associated with combining remote experiments and virtual laboratories. By comparing real experimental and virtual experimental results, it is possible for students to gauge the strengths and weaknesses of different modeling techniques, thus creating a very powerful teaching tool. Design of these combined experiments is time-consuming and expensive, but the potential for sharing resources between institutions may well make this approach viable if there is sufficient interest. Although the Cambridge WebLabs have not yet reached this state of development, the combination of in-depth theoretical pre-preparation and practical experimentation is a step closer to the goal of combining remote and virtual experiments.

V. Future Work

A. The LiLa Project

The Library of Labs (LiLa) project is a pan-European initiative to develop a network of e-labs and supporting materials aimed at undergraduate and graduate students; the LiLa project is co-funded by the European Commission in the context of the eContentplus programme. Among the scheduled developments in the LiLa project is the LiLa web-portal, the entry point for access to the e-labs and other content in the LiLa network. The LiLa portal will provide supporting infrastructure for e-labs such as search and retrieval functions to find appropriate e-labs and related content and a booking and access control system to share and protect the equipment in remote experiments. Pedagogical support provided by the LiLa portal includes collaboration tools and a tutoring system to guide students in their studies and suggest related. The collaborative aspect of the portal will enable group work and interaction between students, but will also increase student interest by taking advantage of the social habits and technologies of the Web 2.0 generation. LiLa content will be delivered as SCORM packages, allowing integration into local learning management systems (LMS).

B. *Projected impact of LiLa on WebLabs and SRM web-suite*

Participation in the LiLa network will benefit developers of e-labs in a number of respects. Firstly, the infrastructure and pedagogical functionality in the LiLa portal can be used to enhance e-labs. For example, one of the difficulties that Cambridge faced, when its Weblabs were used at other institutions, was a lack of appropriate supporting materials; the materials provided were not necessarily appropriate for use at other institutions. Through the LiLa network, lecturers and institutions can develop and share supporting materials for e-labs, reducing the initial cost of integrating an e-lab and ensuring that a range of supporting materials are available. Looking at the CMCL case study, users of the SRM web-suite labs will benefit from the collaboration tools, additional resources, and community support offered by the LiLa network. The development cost of these tools for a single e-lab would in many cases prove prohibitively expensive, but becomes viable when shared between many users.

In addition to the resources provided by the LiLa network, its user-base may also be beneficial for e-lab providers. One of the major difficulties with e-labs is balancing their high costs in the case of under-utilization. By opening up an e-lab to a wider audience, its utilization can be drastically improved; greater usage lowers the per-user running costs, which can potentially be distributed over a number of institutions using the e-lab.

VI. Conclusions

A comparison between a remote experiment, ‘Cambridge Weblab’ and a virtual lab, ‘SRM web-suite’ was presented in this paper.

It is almost certain that virtual laboratories will continue to play a major role in the teaching of engineering and physical sciences in the future, due to their convenience and low costs. Educational applications of more sophisticated virtual laboratory technology, such as the SRM web-suite will ensure that students are well prepared for industry, which is making increasing use of simulations to reduce the need for expensive and time-consuming experimental programmes. Nevertheless, this approach also entails that the students need to know the limitations of different modeling and simulation techniques if they are to successfully apply them.

Remote experiments can provide authentic laboratory experiences, essential for student’s educational development. Many universities will struggle to find the resources to provide more than a small number of conventional experiments, so remote operation of others’ facilities is a potential solution to this problem.

Initiatives such as the LiLa project are essential in order to provide a systematic framework for enabling a collaborative usage of remote experiments and virtual laboratories to meet the educational needs of today’s students.

Acknowledgment

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Simulations in Undergraduate Electrodynamics: Virtual Laboratory Experiments on the Wave Equation and their Deployment.

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***Abstract*—Experiments play a vital role in undergraduate engineering education: They allow students to learn the foundations of engineering in practical hands-on courses. However, lack of funding and increasing costs for equipment makes it harder and harder to supply a complete pool of experiments for large student classes. The EU funded "Library of Labs" project aims to counterbalance this development by creating a EU wide network of remotely controlled experiments and virtual laboratories. Remote experiments are here real experiments remotely controlled over a network, virtual laboratories simulation environments using the component metaphor of a real laboratories.**

In this paper, we introduce such a virtual laboratory developed at the University of Stuttgart; the aim here is to help students, here participating in the undergraduate physics course for engineers, understanding abstract phenomena by visualizing the underlying mathematics. We demonstrate this in a particular use-case, the wave equation and phenomena related to it, as they are discussed in undergraduate physics, and show how to implement this as a simulation in the virtual laboratory.

In cooperation with the physics department a deployment plan for this experiment and related experiments has been created for the lecture "Physics for Engineering" which shall also be presented and discussed.

I. Introduction

Recently, Germany's university system has been changed from the Diploma model to the two-tier Bachelor/Master program: In this study system, following the US university system, students first study a six-semester Bachelor course granting them already access to fundamental skills in their studies and early job opportunities. A successful Bachelor study is the requirement to apply for the second, extended Master studies. Due to this change, many foundational courses in the Bachelor program had to be streamlined and shortened to leave room for courses that would have been taught later in the old Diploma system. As a consequence of this streamlining, courses as fundamental as elementary experimental physics for engineers have been cut down from two to only one semester, and no time is left in these courses to provide students access to practical laboratory hands-on courses in the first semester. The first time students do have contact to real labs is delayed to the second semester where admission to the labs is granted by passing the exams in the first semester.

Unfortunately, this is a very traditional way of delivering physical content: Theoretical background is taught first, followed by practical hands-on courses allowing students to get in touch with practical aspects; the gap between theory and practical applications is here rather extreme, lots of background is simply forgotten in six month. As described in [2] this is so far unfortunate as typical students in a traditionally taught course are learning mechanically, memorizing facts and recipes for problem solving, not gaining a true understanding. Wieman and Perkins note furthermore that most people ("novices") see physics more as isolated pieces of informations handed down by some authority and unrelated to the real world [1].

In reaction to these deficiencies, Schauer introduced an alternative strategy based on integrated e-Learning, defined as "interactive strategy of teaching and learning based on the observation of the real world phenomena by the real e-experiment and e-simulations", see [2]. The procedure here is first to observe the real world phenomena, search for proper information, collect and evaluate data, then present and discuss data and results. Only then comes the explanation and the mathematical formulation of generalized laws and their consequences. The advantage of this procedure is that students have to take an active part in the teaching process. Effective tools for observing the real world are remote experiments and simulations. For studies about the effectiveness of simulations, see [1].

Building a pool of experiments sufficient to cover all of undergraduate physics is of course not an easy concern either, and a rather overwhelming task for a single university. To this end, the University of Stuttgart and ten other European institutions formed the "Library of Labs" network [3], supported by the eContent*plus* programme of the European community. The aim of this network is to setup a common infrastructure to mutually grant access to and share lab experiments and simulations available at the partners, and thus gain access to a sufficiently large pool while sharing the costs and the infrastructure.

II. On Remote Experiments and Virtual Laboratories

Within LiLa, we roughly distinguish between two types of interactive content: So called "Remote Experiments" are remotely controlled physical laboratories, hosted and maintained by one of the participating institutions. Being a scarce resource, remote experiments must be reserved and booked, and only a single student or student group can access them at a time. The University of Stuttgart does currently not provide any remote experiments, but depends on the contributions of parters, for example on the WebLab of the University of Cambridge, or the remote experiments installed at the Institute of Technology in Berlin.

“Virtual Laboratories”, however, are computer simulations that follow the metaphor of a physical lab and form a framework for manifold simulations. An experiment consists here of one or many components grouped together to form a complete simulation of a physical or mathematical phenomenon. The behavior of the simulation again is measured by one or several meters, where both — the experiment and the meters — are computer algorithms. These algorithms can be either taken from a pool of already prepared experiments, or can also be modified or created by the students as required. Examples for such virtual laboratories are the “Modelica” system developed by our partner, the University of Linköping in Sweden, capable to simulate any coupled system describable by differential equations, the Easy Java Simulations (EJS) project [9], [10], or the VideoEasel system maintained and developed at the University of Stuttgart; the latter laboratory is specialized for simulating many-body particle systems, systems that are described by simple microscopic rules from which complex and often surprising macroscopic behavior emerges. A typical example for such emerging behaviour is that of “phase transitions”[4], the sudden change of a physical quantity under the change of a parameter of the system, as for example boiling of water at $100°C$. Experiments on such phenomena using virtual laboratories have been described in the past by one of the authors[5].

The common aspect of Virtual Laboratories is that, instead of only presenting a fixed, pre-programmed simulation, they reveal parts of the simulation engine and allow their users to *program* or *model* the dynamics to be simulated, and not just interact with the simulation as an electronic model of a physical experiment. Virtual Laboratories are, hence, a considerably flexible environment *for* simulations than just a specific simulation. While the underlying principle of EJS or Modelica is to describe physical processes by differential equations, VideoEasel only considers very simple time- and space discrete automata. Besides this simplicity, the large number of such simple systems coupled together generates interesting complexity and phenomena worth studying.

Even though the focus of the VideoEasel system is that of many body systems and how complex macroscopic behavior emerges from simple microscopic rules, we shall here describe a group of experiments not based on statistical mechanics, but one of the fundamental equations of physics, the wave equation. It describes spreading of all types of waves, let it be sound, water waves; phenomena like reflection and refraction are described by the same set of equations. Maxwell's equation of classical electrodynamics can be simplified to wave equations of the electric and magnetic field under certain conditions[6], and the Schrödinger equation of quantum mechanics also behaves like a wave equation with a specific diffusion relation. The latter has important consequences in physics, namely that phenomena like interference patterns known from light are also observable for rays of material particles. It is one of the fundamental experiments of quantum physics to measure this pattern which is not explainable by the model of classical particles otherwise.

These experiments, their simulation, and many other related, will be described in the section IV below.

III. Mathematical Background

In this chapter, the elementary mathematical background on the wave equation is given. Its properties discussed in this section are typically taught in undergraduate physics classes and hence need to be addressed by any type of simulation; specifically, they must be reproduced correctly to provide sufficient insight into the behaviour of waves.

The (scalar) wave equation is the following second-order hyperbolic differential equation:

$$\frac{\partial^2 \psi}{\partial t^2} = c^2 \triangle \psi \tag{1}$$

where ψ describes the *amplitude* of the field and c is the speed of the wave propagation. The wave equation describes phenomena like sound waves, electromagnetic waves or, in the approximation of small amplitudes, water waves. More important than the equation itself are, however, its properties every student of physics or engineering should be aware of, and that a suitable simulation must be able to reproduce:

- The wave equation is a linear equation; this has the important consequence that the sum of two solutions ψ_1 and ψ_2 is again a solution, i.e. $\psi_1 + \psi_2$ solves the wave equation as well. That is, the *superposition principle* holds: Waves from two sources simply add linearly without interfering each other.
- The wave equation has two noteworthy special solutions: First, *planar waves*

  $$\psi(\vec{r}, t) = A \cos(\vec{k} \cdot \vec{r} - \omega t + \phi) \ ,$$

  where $\vec{k}$, the so-called *wave vector*, points into the traveling direction of the wave, ϕ and A are arbitrary and $|\vec{k}|c = \omega$ holds. Second, for the special case of three dimensions, *spherical waves*

  $$\psi(\vec{r}, t) = \frac{1}{|\vec{r}|} \left(A_{\text{out}}(|\vec{r}| - ct) + A_{\text{in}}(|\vec{r}| + ct) \right) \ ,$$

  where A_{out} and A_{in} are arbitrary functions and describe waves outgoing from and ingoing into the origin. A spherical wave created by a harmonic oscillator at the origin would correspond to the solution $A_{\text{out}}(u) = \cos(u + \phi)$ and $A_{\text{in}} = 0$, for example. Unfortunately, a spherical wave solution of similar simplicity does not exist for two dimensions (or any even dimensional space), which is, however, the case covered by the simulation. In this case, one only has

  $$\psi(\vec{r}, t) = c \int_0^{t-1/c|\vec{r}|} \frac{cos(\omega t' + \phi)}{\sqrt{c^2(t-t')^2 - |\vec{r}|^2}} \, dt' \ ,$$

for the initial condition of a harmonic oscillator at the origin that starts oscillating at $t = 0$. Unlike the three-dimensional case, the solution due to a short excitation at the origin does not stay on the light cone, but fills the inner of the light cone.
The important lesson is, nevertheless, that all these solutions form only different generating systems of the solutions of the wave equation, and one can, for example, generate a plane wave by a suitable linear combination of spherical waves. This is also known as *Huygens' Principle* and one of the important topics covered in undergraduate physics.

- A third important property is the conservation of energy: That is, the integral of the square of the amplitude over the whole space remains constant. The square root term in the two-dimensional solution or the $1/r$ term in the three-dimensional solution can be understood as manifestations of this principle: As a spherical wave propagates from the origin, its square amplitude must dilute proportionally to the surface of the sphere, i.e. $1/r^2$ in three or $1/r$ in two dimensions.
- The above solutions of planar and spherical waves hold only in free space; if the wave is confined by obstacles or walls, these are mathematically described by boundary conditions that need to be satisfied by the solution. While many possible boundary conditions exist, two special choices are of primary interest: First, the so-called *Dirichlet* boundary condition which requires ψ to vanish at the edge of the domain, and which describes a fixed end; and the *Neumann* boundary condition at which the spatial derivative of ψ in normal direction vanishes, also denoted as "loose end". The important properties are here that upon reflection on a fixed end, a wave is reflected back with its amplitude reversed, whereas on reflection on a loose end the wave traverses back without a phase change. A simulation of the wave equation should also reproduce these effects correctly.
- Waves interfere, creating interference patterns or standing waves; a wave reflected by an obstacle and reflected back will, for example, interfere itself and will create nodes and anti-nodes in the medium at fixed (non-time-depending) positions. This effect is called "standing waves". A simulation should also be able to demonstrate this effect.
- Waves are diffracted at obstacles. Quite unlike classical particles, waves can partially travel around obstacles, and only obstacles larger than the wavelength can severely impact the propagation of waves. One particularly important experiment on diffraction is the double-slit experiment, creating a very typical interference pattern. The very same interference pattern is, surprisingly, also visible for particles, showing that particles also have a wave nature. This is one of the very fundamental principles of quantum mechanics.

A. A Discretization of the Wave Equation

The VideoEasel system introduced above is only capable of simulating discrete systems, i.e. systems that are discrete in time, space and states; continuous differential equations are out of question. While software exist capable of solving such equations, for example in the form of the "Modelica" toolkit provided by the University of Linköping, their complexity is beyond the all-purpose approach of the virtual lab designed in Stuttgart. Hence, the goal is a suitable discretization of the wave equation (1) that is able to reproduce the phenomena described above, and is hence both didactically suitable and mathematically correct.

At first sight, a suitable approach would be the straightforward discretization of the wave equation by a discrete Laplacian and a discrete time derivative, hence replacing it by a scalar second order difference equation. However, it turns out that this approach is not particularly useful, especially energy conservation is considerably hard to ensure in this approach. A considerably more interesting and fruitful approach is that of proposed by H.J. Hrgovčić[7] in his thesis: Similar to the Dirac equation replacing a scalar differential equation by a vectorial equation, Hrgovčić replaces the scalar amplitude of the wave equation by four flux components that describe the field flux into and out of vertices in a quadratic lattice.

In this approach, the wave equation is replaced by a difference equation that operates on the dual lattice of a spatial quadratic lattice, i.e. on the vertices that connects lattice points with their four nearest neighbours. Let $\vec{r}$ be a point on the original spatial lattice, then the vectorial field $\vec{f}$ describes the four components of the field flux running into location $\vec{r}$ coming from the left, right, top and bottom neighbour. We write the four components as

$$\vec{f}(\vec{r},t) = \begin{pmatrix} f_{x,+} \\ f_{x,-} \\ f_{y,+} \\ f_{y,-} \end{pmatrix} (\vec{r},t) \quad \vec{r} \in \mathbb{Z}^2$$

keeping in mind that $f_{x,+}$ is the flux ingoing into the vertex at location $\vec{r}$ from its right neighbour, etc. Let $\vec{g}$ now the vector of the outgoing fluxes from vertex $\vec{r}$ to its neighbours, i.e.

$$g_{x,+}(\vec{r},t) = f_{x,-}(\vec{r}+\vec{e}_x,t) \qquad g_{x,-}(\vec{r},t) = f_{x,+}(\vec{r}-\vec{e}_x,t)$$
$$g_{y,+}(\vec{r},t) = f_{y,-}(\vec{r}+\vec{e}_y,t) \qquad g_{y,-}(\vec{r},t) = f_{y,+}(\vec{r}-\vec{e}_y,t)$$

then the following matrix equation describes the fluxes under the wave equation:

$$\begin{pmatrix} g_{x,+} \\ g_{x,-} \\ g_{y,+} \\ g_{y,-} \end{pmatrix} (\vec{r},t+1) = \tag{2}$$
$$= \frac{1}{2} \begin{pmatrix} -1 & 1 & 1 & 1 \\ 1 & -1 & 1 & 1 \\ 1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 \end{pmatrix} \begin{pmatrix} f_{x,+} \\ f_{x,-} \\ f_{y,+} \\ f_{y,-} \end{pmatrix} (\vec{r},t) \,.$$

This equation is now finally suitable for its implementation in VideoEasel. For visualization efforts, it is also often useful to display the field amplitude directly: It is given as the sum of all four incoming fluxes; the intensity resp. the energy of the field is given as the sum of the squares of the components. It is now readily seen that the matrix in equation 2 is orthogonal, hence preserves the lengths of vectors, and by that also the energy of the field, as required. Some additional modifications not to be discussed here also allow the simulation of reflection on loose or fixed ends, and — as surprising as it may sound — even though the underlying lattice is clearly not isotropic, the simulation generates almost perfect spherical waves. Needless to say, as the equation is linear, the superposition principle holds, and effects like the construction of planar waves from spherical waves can be demonstrated. Examples will be shown in the next section.

IV. Experiments

In this section, a couple of typical experiments shall be shown to demonstrate the usefulness of the Virtual Laboratory. Fig. 1 demonstrates the linear superposition of two wavefronts generated by two point excitations and the spherical wave created by an oscillator in the middle of the screen. The superposition principle is due to the linearity of the wave equation; in this simulation, linearity also only holds approximately because amplitudes of the excitation are limited; consequences from this limitation remain rather limited, though. It is further interesting to note that the generated waves are almost spherical, despite the simulation running on a square lattice.

The second set of figures (Fig. 2) demonstrates Huygens' Principle: A row of point-wise oscillators generates a wavefront that is almost planar by superimposing the spherical waves seen in Fig. 1. On the right hand of Fig. 2, a planar wave travels partially around a vertical obstacle, generating two spherical wave fronts behind the obstacle: This wave pattern can be understood by being generated by a vertical row of oscillators similar to that constructed in the first experiment, though interrupted by the obstacle in the middle. The oscillators at the top and bottom edge of the obstacle are then generating the spherical waves traveling into the "shadow" of the object which blocks the incoming planar wave. It is also interesting to note that the planar wave reflected back by the obstacle interferes with the incoming wave, forming a standing wave. Node lines become much more visible in the real animation than on the picture, though.

The third example shows the famous double-slit experiment (cf. Fig. 3): An incoming planar wave is blocked by a double slit, forming a typical interference pattern behind the slit. In a true-life experiment, laser light detracted at a double slit generates the very same pattern, becoming visible on a screen placed behind the slit. What is remarkable on this experiment is that a very similar pattern is also observable if the laser beam is replaced by a particle ray, quite contrary to common intuition. It is one of the elementary experiments in quantum physics. Following Huygens' principle, the very same interference pattern is of course generated by two oscillators placed at the position of the slits, as shown in the right-hand side of Fig. 3.

V. Integration of Virtual Laboratories and Remote Experiments into Lecture

The aim of LiLa is to share all the experiments participating institutions have to offer, enabling lecturers to select from almost unlimited resources for their lectures. The topic to be discussed in the following section is hence how to optimally integrate such resources into lectures, to mention potential challenges and how to overcome them, or in short, to give interested lecturers guidelines for optimal deployment of the LiLa material.

We are developing these guidelines again from our experiences using remote and virtual experiments in the lecture "Physics for Engineering", one example being the wave equation introduced in the sections above.

A. Initial Situation in "Physics for Engineering"

"Physics for Engineering" is a first year freshmen course taught to students of all kinds of engineering studies, including mechanical engineering, aerospace engineering and many others. Currently about 1300 students are attending the course. Due to the high number of participants and limited room capacity, lecturers are giving the same course twice a day, giving all students a chance to attend. The curriculum, recently modified to a Bachelor-Master study program, does not include any mandatory exercises for this specific lecture, nor does the tight schedule allow room for a mandatory lab course. However, experiences have shown that students participating in optional homework exercises handed out by the lecturer have a considerably higher chance passing the final written exam. Hands-on lab courses have not been part of these homework exercises, so far, however; the aim of this first pilot study is to offer students optional learning alternatives to the also optional pen-and-paper exercises.

The University of Stuttgart already offers an electronic Learning Management System (LMS) which provides information on the lecture, forums, questionnaires and material for self-study for this and many other lectures offered by the University. It is a well-accepted system known to both lecturers and students. Clearly, the LiLa experiments will be integrated into this system, here as applets running in a browser. This interactive content is then either used for self-study, or — in this starter project — in small student groups of at most 12 people a time, supported by teaching and technical staff of the physics department and the computing center.

We first performed an initial questionnaire to evaluate the motivation and interest of students in such optional courses, and to find out how much time they would have available for such additional courses. Around 87% are interested in participating in optional lab exercises, 23 % are willing to spend between half an hour to one hour for doing the exercise, 37,5 % are willing to spend one hour to one and a half hour and 30 % are able to spend one and a half hour to two hours. The remaining students may either have less than half an hour or more than two hours available for such courses. Apparently, the interest in such optional experiments is rather high, and the time students are able to invest into such courses is between half an hour and two hours.

B. Deployment Plan for the Exercises with Online-Experiments

The first step to do is to evaluate which experiments, virtual or remote, fit best into the content of the lecture. For that we

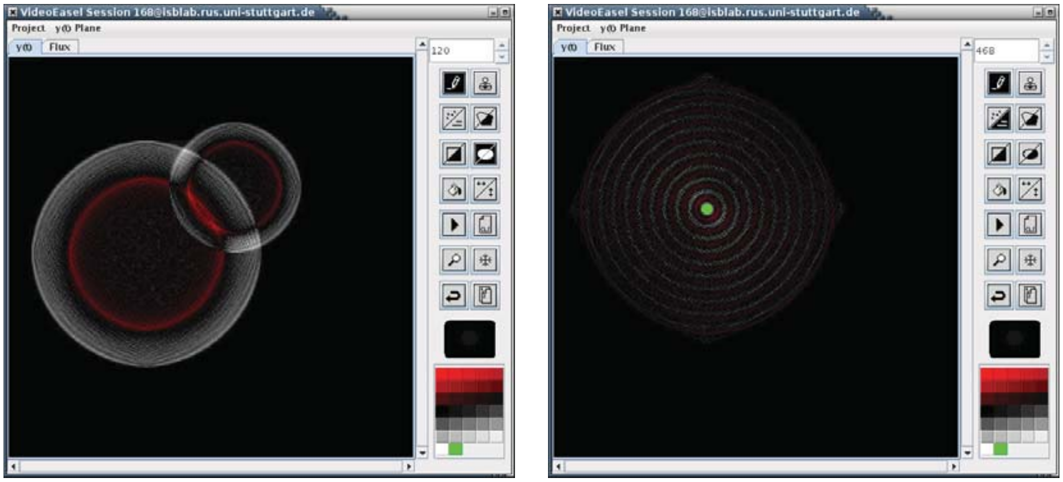

Fig. 1. Superposition of two point-excitations (left) and a spherical wave created by an oscillator (right)

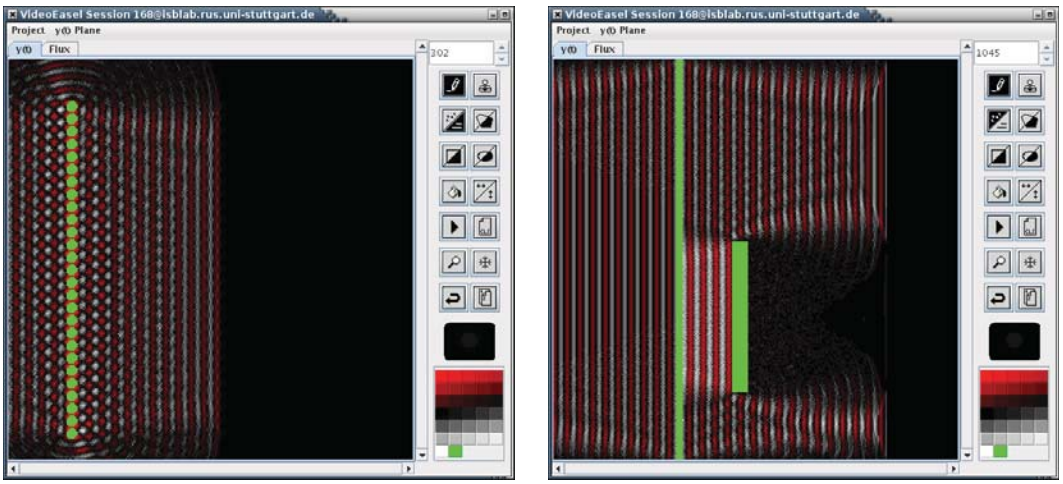

Fig. 2. Demonstration of Huygens' Principle (left), and a planar wave being blocked by an obstacle. Note that spherical waves travel into shadow of the obstacle.

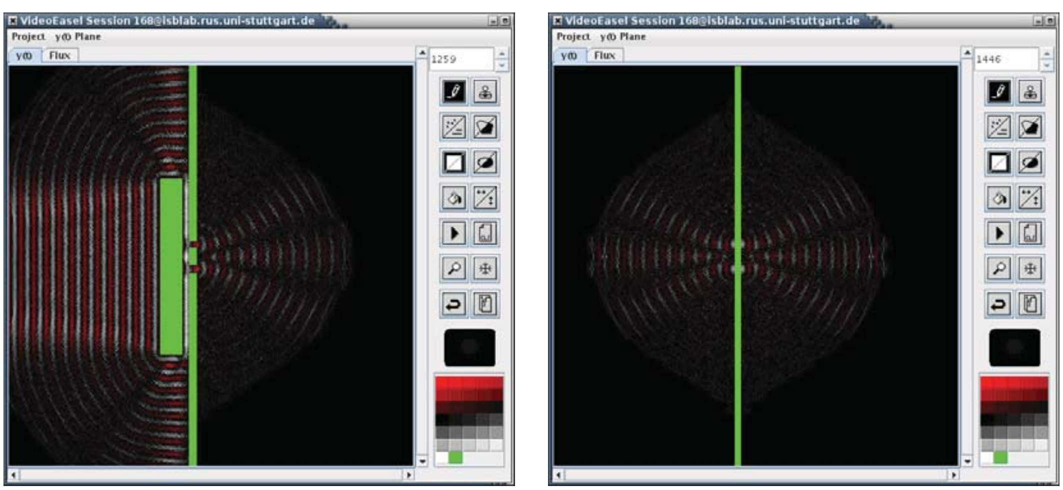

Fig. 3. The famous double slit experiment (left). The same interference pattern is generated by two oscillators replacing the slits (right).

compared the existing contents of the lecture with experiments available in Stuttgart and Berlin. For a first pilot phase we wanted to set up a manageable amount of experiments and decided to restrict the number of experiments to one per month.

Afterwards, we had to develop a structure for each of the experiments itself; this includes a both the organizational framework for the experiments as well as its technical realization which should fit into the Ilias LMS. We agreed on structuring experiments into the following three phases:

- **Orientation Phase:** This first phase allows students to familiarize themselves with the online experiment; an abstract on experiment is presented that contains a short description of experiment and the task to perform, the definition of the learning goals that should be reached, and a small pre-test evaluating the knowledge of the students.
- **Execution Phase:** This is the main phase of the exercise. Here the given tasks should be mastered by the students, i.e. running the experiments and measuring the results.
- **Review Phase:** The purpose of the last phase is to check the progress of the students. They pass again a small test, evaluating the knowledge obtained from running the experiment.

In the pilot, we also included an additional questionnaire in the review phase to gain some understanding on how students think about these exercises. Specifically, we want to know whether they believe to learn better with online experiments and whether their motivation looking into physics is increased by running experiments. Results of this questionnaire are not yet available and will be evaluated at the end of the winter term.

C. Motivational Aspects

Providing additional learning material helps little if students aren't motivated to use them; in this section, possible stimulations shall be discussed to optimize the impact of the provided material.

While providing experiments, and hence a chance to work actively instead of consuming content is a motivation by itself, realistically speaking this type of motivation might only work for students that are intrinsically motivated already. However, freshmen are very busy and the course schedule for the first year is already very packed by lectures and courses of manifold kind. This leaves, unfortunately, only very limited time for *optional* exercises, and it seems also very unrealistic to change this situation in short-term; hence, we face a situation that makes it considerably hard to clarify the importance of additional work to be performed by students.

Currently, we consider the following mechanisms to build up an additional force to drive students:

- Students participating in online experiments gain extra points for the final exam at the end of the course. While in this strict sense legally problematic — an *optional* course element cannot become a requirement for passing the exam — a potential modification would be that points collected from running experiments are bonuses that can cancel errors made in the written exam while leaving the error thresholds for the grades otherwise untouched. That is, a 100 % error free exam would still count as an A grade, regardless of whether experiments have been performed or not, but a lower B grade could be improved by having participated in lab courses. Collecting bonuses for the exam is an already accepted and tested mechanism in other lectures.
  What might be problematic is testing students for continuous attendance of the lab courses; while less a problem for tutored courses, it is more a problem for students that use experiments for self study at home. The former type of student support remains, however, only available as long as we have funding from the LiLa project and might be not available beyond the pilot phase.
- An additional source for motivation might be the integration of a contest into exercises, asking students to provide answers or experiments for an open ended question. Such a question could be to provide an experimental setup that demonstrates interference of waves, or the relation of the strength of a wave from the distance of its origin, etc. At the end of the term the best student would be granted a price, e.g. a free iPod.
  Clearly, such a contest can never be completely objective or completely fair for the suggested open-ended exercises; results might be copied from fellow students as in exams, but we have a much less controlled environment here where chances for intellectual theft are considerably higher.

In our current planning, the wave equation experiment will provide a good framework for interesting open-ended questions to be posed that requires students to perform the experiments by themselves. The next section will propose a couple of exercises and questions we plan to provide. Unfortunately, results are not yet available at this time.

D. Deployment and Scheduling

In our current planning, the wave equation exercise is scheduled to the end winter term, following the schedule of the lecture; it is likely the last and final exercise in this course, and thus offers a good opportunity to state open-ended questions as mentioned in the paragraph above.

One of the challenges we have to face is the rather high number of participants; as mentioned earlier, we expect roughly 1300 students in the winter term. While we definitely hope that most of them will participate in our hands-on course, checking their solutions for correctness is a major hassle for a small team of assistants and tutors. We propose the following solutions to address this problem:

- Automatic testing of results by the Ilias learning management system. This requires, of course, that exercises are stated in a way that allows automatic testing, e.g. by requiring students to find a numeric value by measuring a phenomenon, or by stating multiple-choice exercises. A potential exercise here would be to ask students to measure the amplitude of a spherical wave as a function of the distance from the oscillator; it can be seen from the explicit solution above — or by considering the conservation of energy — that the amplitude must decay as $1/r$. Since our laboratory also includes a SCORM integration, such exercises could also be stated within the laboratory system itself, forwarding any measurement results directly to the Ilias system.

- Peer reviewing. Here experimental setups created within a small group of students, say two to three, are reviewed by a second, independent team. Each group would have to prepare a report about their findings and experimental setups which is then checked by peers. A possible task would be to design an experimental setup demonstrating Huygens' principle and report on the results.
- As a modification of the above ideas, small modifications of the same assignment could be handed out to individual students instead of student groups; alternatively, combinations of the ideas above are possible were a first student group built the experiments and a second group checks for proper results and enters the measurement results into the Ilias system.

The aim of all exercises is of course to ensure that students gained insight into the wave equation while keeping them motivated to participate. Peer reviewing imposes the risk of students dismissing reports from their fellow students, or creating unfair review results due to varying background knowledge at the reviewers themselves. However, it also creates an additional learning effect by requiring student reviewers to go over the material once again. At this time, we do not yet know whether our ideas will work and we cannot yet present results, however, we surely never find out without trying. First experiences will become available end of the winter term.

VI. Results and Future Prospects

While we haven't had the chance to use the virtual laboratory for students, we nevertheless already run an initial test-case with a simple flash-based experiment created by the University of Colorado [8], and used here as a "warm up"; about 250 of 1300 participated in this test case, but the first results look very promising: A first analysis of the online-questionnaire shows that around 90% of the students enjoyed the exercise with an online-simulation. Also around 90% of them stated that they are more motivated to deal with the content of the lecture due to the online-simulation. Around 85% were thinking that their learning success will be higher with doing these exercises. For around 90% of the participants the content of the exercise was easily comprehensible.

Unfortunately, instructions how to handle the online experiment were not yet sufficient; about 45% reported insufficient instructions, requiring us to enhance the descriptions and being more precise on the expected tasks. For example, we gave no information how to round the numerical results, and the Ilias system was not flexible enough to accept results rounded to a different number of digits than we expected, causing it to rate some of the results as incorrect, and hence demotivating students. Of course, once we would have built up a working and tested corpus of online experiments, such problems will be avoided; what we should learn here is, however, not to underestimate the effort that needs to go into testing.

Exercises were accompanied by online questionnaires to be filled out by students using the exercises for self-study; additionally, we were able to reserve work-stations for groups of twelve students in the computer department on campus, allowing them to meet with tutors and experts to help them with their tasks. While it is unclear whether we will be able to offer on-site help in the future, it did allow us now to interview the participants directly, and we will be able to report our findings at the end of the term as soon as the data is collected and analyzed.

Concluding, we hope to be able to enrich the engineering studies by providing exciting, entertaining and instructural experiments students are able to perform at home any time they like; however, as we have already seen, providing just the experiments themselves is insufficient: they need to be embedded into a pedagogical strategy and must be complemented by sufficient instructional material telling students what the experiments are about, how to perform them, and which results we are expecting from them.

VII. Acknowledgments

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Some Research Questions and Results of UC3M in the E-Madrid Excellence Network

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An approach for Description of Open Educational Resources based on semantic technologies

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<e-Adventure> Introducing Educational Games in the Learning Process

del-Blanco, Ángel; Fernández-Manjón, Baltasar; Marchiori, Eugenio J.; Moreno-Ger, Pablo; Torrente, Javier

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Influence of Libre Software in Education The blogs planet case

González-Barahona, Jesús M.; Gregorio, Robles

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Automatic Guidance Tools for Enhancing the Educative Experience in Non-Immersive Virtual Worlds Preliminary results from project V-LeaF

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Enhancing Authoring, Modelling and Collaboration in E-learning environments: UNED research outline in the context of E-Madrid excellence network

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Some Research Questions and Results of UC3M in the eMadrid Excellence Network

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Abstract— **Universidad Carlos III de Madrid is one of the six main participating institutions in the eMadrid excellence network [73], as well as its coordinating partner. In this paper, the network is presented together with some of the main research lines carried out by UC3M. The remaining papers in this session present the work carried out by the other five universities in the consortium.**

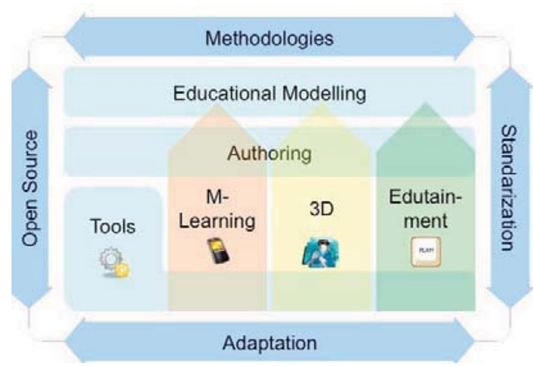
Keywords- e-learning, technology enhanced learning

I. INTRODUCTION

eMadrid [73] is the name of the Excellence Network about e-learning funded by the Regional Government of Madrid. Its members are the Universidad Carlos III de Madrid (UC3M), who acts as a coordinator, Universidad Autónoma de Madrid (UAM), Universidad Complutense de Madrid (UCM), Universidad Politécnica de Madrid (UPM), Universidad Rey Juan Carlos (URJC) and Universidad Nacional de Educación a Distancia (UNED), together with a large number of associated companies and educational institutions. The aim of the network is to provide leadership and perform advanced research in the area of e-learning.

Much progress has been made in recent years in the field of e-learning, but important challenges lie ahead for this technology to maximize its impact. Questions such as the following are of great interest for the future: What authoring tools may be provided so that creating educational material is as smooth and simple as possible, so that authoring can be incorporated into the educational process by all agents involved in it, including the students themselves? What impact do recent advances in web technology, such as the web 2.0 and semantic web technologies, have on education? How can the open source approach boost learning management systems? What new teaching models and methodologies can be supported by educational tools? What role does standardization play for e-learning formats and tools and how it can advance the state of the art? How can the integration of games, that are having such a success among the young, impact learning? How can we support formal and informal learning with the use of mobile devices, which are in the pockets of almost everyone?

Although the research to be carried out is intertwined and related, the consortium has organized its work around the following research lines: (1) Educational modelling (including collaboration & virtual communities), (2) Educational methodologies based on ICT, (3) Standardization of tools and educational content, (4) Platforms and tools for e-learning, (5) Adaptation, adaptability, and accessibility, (6) Immersive 3D learning, (7) Edutainment (Integration of games and simulations in Virtual Learning Environments), (8) M-learning (Mobile and ubiquitous learning), (9) Authoring & Applications of Web 2.0 and Web 3.0 to e-Learning, and (10) Free and Open Source Software. This figure shows the relationship among them:



We distinguish 3 main phases in the educational process: the phase of educational modelling, where the learning process is planned, the authoring of the needed learning material and assessment, and finally the tool-based deployment and enactment. For each of these main phases, we have one research line. But apart from the mainstream application areas, there are 3 promising areas, which deserve particular attention. These are m-learning, 3D virtual worlds, and game-oriented learning, which cut across the main areas. Due to their future importance, we study them in detail in independent research lines.

All this is framed by educational methodologies (giving a pedagogical underpinning to the learning process), standards (enabling interoperability among tools), adaptation in the most general sense (to classes of users and their abilities and context), and development principles (among which we concentrate on open source).

This paper is the first in a special session about the eMadrid excellence network. The remaining 5 papers by the other consortium partners touch upon several of the research lines mentioned. The paper by UCM describes their approach to introduce educational games in the learning flow. URJC presents the influence of libre software in education on the basis of a case study. Apart from open source programs, open educational resources are acquiring increasing importance. The paper by UPM covers a proposal for the use of semantic web techniques for making their discovery more effective. UAM describes how virtual 3D technologies can be used for learning. UNED's paper proposes a new paradigm for authoring that takes advantage of semantic web techniques.

The Universidad Carlos III de Madrid participates in all 10 research lines identified for the network, but, for the purpose of this paper, we will have sections about all the topics except two: the one on edutainment (we will make some reference to it in the section about 3D worlds) and the one on open source software, although most of the developments carried out are open source software. We will refer to them in several sections, most notably in the one about frameworks and tools.

II. EDUCATIONAL MODELLING

Learning scripts are external representations of the procedures and relations among participants and elements in a learning flow. Based on instructional design techniques to translate pedagogical models into a structured plan of activities and materials, scripted courses help students to focus their attention on relevant resources and activities [1]. There are several formats to deliver structured learning flows, ranging from pure text based instructions to graphics and diagrams of activities. Even if the structure is the same, different delivery methods may affect students' performance on the course.

On the way to capture all the richness of human interactions into a learning design, authoring tools promote Domain Specific Languages [2] such as IMS Learning Design [3], LDL or LAMS. The use of modelling languages implicitly imposes three phases in the course life-cycle: authoring, deployment, and enactment. For authoring, modelling languages allow instructors to define all interactions and resources in the course in a computer-readable way. Deployment is devoted to allocate resources and assign actual course participants to the abstractly defined roles. The course starts at the enactment phase, where instructions given by the script are delivered and interactions among course participants take place.

The number of tools aimed to support the course life-cycle for educational modelling languages designs is increasing rapidly and the market is willing to adopt new techniques of learning delivery. Despite these significant efforts, there still exist open issues in the field, requiring further research to be addressed. Main open questions include usability of the different approaches and its relationship with technology adoption; identification of patterns and its expression in form of scripts; and support of emerging learning techniques related with the wide acceptance and potential of Web 2.0 tools in the field of collaboration and course adaptability.

IMS Learning Design [3] is considered the *de facto* standard for educational modelling. It is intended to support a wide range of pedagogical models. General-purpose authoring tools such as RELOAD, COSMOS or CopperAuthor offer a close-to-specification interface which cannot be used by non-experts in the field. As a result of the difficulties shown during course edition, there is still a low level of adoption of the specification. Current research guidelines promote the inclusion of a new abstraction layer to reduce the gap among the technologies and the practitioners.

A different approach to improve usability of authoring tools and therefore to increase the adoption of IMS Learning Design relies on the identification of patterns of interaction [4]. Patterns are widely accepted in the field of collaborative learning and, in the long term, allow instructors to identify best teaching techniques.

Script-based learning, as well as the whole area of e-learning, has recently received the positive impact of the success of Web 2.0 techniques, whose tools promote participation, interaction, and new forms of communication among users [5]. The inclusion of emerging modes of interaction on educational patterns presents a challenge that can be faced from different perspectives. On the one hand, there is a great potential on the development of new learning strategies that rely on emerging web features. On the other hand, the distributed nature of the web hinders the creation of scripted courses due to the difficulty to express during authoring how course participants will interact with a service, whose nature and usage details would (and will) change on time.

The UC3M group contributes to the adoption of IMS Learning Design with GRAIL, a compliant runtime environment integrated with the .LRN Learning Management System [8]. We considered that the strict division of the course life-cycle of authoring, deployment, and enactment imposes a severe drawback for the adoption of the specification. Current developments are focused on the provision of an authoring-phase functionality once the enactment phase has started. Following the metaphor of a cockpit, the tool incorporates facilities for actions such as editing existing resources, creating new ones, or modifying conditions imposed to the course. Another research line that makes use of GRAIL is focused on service integration within structured scripted learning flows. The UC3M group studies the impact of the inclusion of third party services in the course life-cycle and develops models to perform the actual integration [7]. Software components built on top of GRAIL allow the evaluation of the proposed solution.

III. ICT-BASED EDUCATIONAL METHODOLOGIES

The introduction of Information and Communication Technologies (ICT) in the educational setting opens a wide range of learning possibilities. Flexibility, both regarding temporal as well as spatial constraints, is traditionally awarded as a key advantage of the use of ICT in learning. ICT facilitate the delivery and accessibility of learning resources, the use of richer multimedia and helps fostering collaboration and interaction between students and teachers, as well as between students themselves. Thus, far beyond the direct translation of traditional face-to-face methodologies, ICT bring a rich set of expectations for adapting such methodologies and introducing new ones to motivate the students and improve their learning outcomes.

Learner's assessment is perhaps one of the areas where this combination is proving to turn into a richer symbiosis. ICT strongly facilitate the management of the assessment process, leveraging the teaching burden associated to it. But apart from the logistic support, ICT empower potential benefits of the assessment process (for example, fostering immediacy of feedback) as well as open new scenarios for student evaluation.

Systems based on multiple-choice questions (MCQ) are the most extended Computer-assisted assessment method. Most Learning Management Systems, such as .LRN [8], Moodle [9], Blackboard [10], etc., include the possibility of writing and taking MCQ tests as part of their functionality. In [11], a thorough analysis of MCQ from a pedagogical assessment standpoint is provided, together with an assessment framework and a set of feedback principles for improving their effectiveness. From a didactic point of view, immediacy is one of the key advantages of MCQ, as automatic feedback can be provided to the learner instantaneously. Such immediacy is considered a critical requirement for successfully supporting the student learning process. Despite of their wide use, MCQ suffer from some limitations as stated in [11] and alternative methodologies can be considered more appropriate depending on the learning outcomes to be assessed.

Web 2.0 applications in learning are based on constructivist theories. Web 2.0 technologies allow the students to actively participate in the learning process, interacting with their peers and the instructor and even collaborating in the generation of learning materials. Moodle is an example of LMS inspired on constructivism. The use of Web 2.0 technologies for assessment focuses typically on the use of blogs [12] [13] and wikis [14] [15], as simple but flexible portfolios, which provide an easy-to-use framework for personal reflection, discussion and collaboration.

Pedagogic theories advocate the active involvement of the student not only in the learning process, but in the assessment activities too [16]. This objective is easier to achieve with ICT, using collaborative tools for discussing and agreeing rubrics and assessment criteria or peer assessment systems for involving the learners as assessors themselves [17].

Finally, existing online video-conference technology allows for the deployment of richer interactions, close to face-to-face ones. Remote presentations and questioning can be easily deployed today with minimum technological infrastructure (a simple webcam and web-based software). Viva exams are an example of a traditional methodology that can be directly translated to the virtual world using this technology. But ICT can also help to overcome traditional disadvantages of viva exams, such as the lack of persistence or the difficulty of applying homogeneous qualification criteria. Regarding the first point, online meetings are easily recorded, allowing the archive of evidences in a similar way to written exams. Such archives can be then used for future review, potential reclamations or simply as a reference for future students. They can also help to improve the quality of the assessment process, providing a set of samples that can be referred to as examples of how a concrete case should be evaluated. This is one of the objectives of the WebCEF project [18], where a showcase of video samples is being built for assessment of English as a second language according to the European CEF competences reference framework.

Lastly, some concerns related to the use of ICT for assessment should not be ignored. Security remains to be an active issue regarding the deployment of e-assessment formally. Potential risks include impersonation and cheating as major problems. Current solutions are typically based on the existence of a controlled environment for the assessment. Nevertheless, as such a requirement implies face-to-face settings, an intense research activity is going on to alleviate such security issues while maintaining the e-learning facilities and advantages, based on the use of video images, motion control etc.

UC3M is actively exploring new assessment scenarios and methodologies based on the use of ICT, mostly in the context of the iCoper European Best Practices Network. In this sense, we have focused particularly on two main research lines:

The work developed on adaptive peer review methodology [19] addresses the combination of active participation of the student in the assessment process together with adaptation to foster the motivational and pedagogical effectiveness of the task. ICT is here applied both to support the process logistics and, mainly, to perform the adaptation to the students' profiles.

In collaboration with the Knowledge Media Institute (The Open University), the use of online meetings and video-conference for assessment in different domains, courses, levels and countries is being explored at UC3M. The analysed case studies cover a complete set of situations, ranging from formative to summative purposes and from individual to collaborative (team-project) assessment.

IV. Learning Content and Tools Standardization

Nobody denies the importance, even more the necessity, of the existence of standards to organize any particular technical field to allow the interoperability of tools. Standards make data independent of concrete tools: they unfasten data from tools. The main objectives of standardization can be summarized in the following points:

- Enabling interoperability among platforms
- Protection of investment on content development
- Exchange of content locally and globally

In the context of e-learning content, several standards have been developed in the recent past. IEEE LOM [22] is a standard that specifies the syntax and semantics of Learning Object Metadata, defined as the attributes required to fully/adequately describe a Learning Object. Learning Objects are defined as any entity, digital or non-digital, which can be used, re-used or referenced during technology-supported learning. SCORM [20] is a set of technical specifications for e-learning software products. It tells programmers how to write their code so that it can "play well" with other e-learning software. Specifically, SCORM governs how online learning content and Learning Management Systems (LMSs) communicate with each other. SCORM does *not* speak to instructional designs or any other pedagogical concern, it is purely a content-oriented standard. There is also a large group of specifications from the IMS Global Learning Consortium (IMS GLC) [21]. Some IMS specifications are: Questions and Test Interoperability (QTI) for assessment purposes, Learning Design (LD) concerning the instructional model, Common Cartridge (CC) to package learning contents using Content Packaging (CP), Learning Information Package (LIP) for learning information and Reusable Definition of Competency or Educational Objective (RDCEO) related to competences. Most of these have not acquired the status of a standard given by a standardisation organization, but in their absence have acquired wide-spread use.

Andrew S. Tanenbaum [24] highlighted the importance of standards in a comical way by saying "the nice thing about standards is that there are so many of them to choose from." And this is exactly the key to success. Too many standards for the same topic, implies that there is no agreement and therefore the power of standardization is lost again. There have to be as few as possible standards that are as good as possible. But what does "good" mean, from a general point of view? Different users and tool vendors might need quite different applications of the same format. With the aim to fulfil users' and stakeholder's requirements, standards tend therefore to become quite extensive and complex. But then we arrive to another problem: since the standards are so complex, only subsets are implemented in tools. And again different subsets of the same standards, means again no standard and no interoperability.

We believe that standards should be designed to be *robust* against subsetting. This has several implications. One is that a particular concept should be expressible in just one possible way using a selected standard. This is why a good conceptual model is essential from the very beginning. Besides, standards should not be considered complete when experts just defined them; they should incorporate some kind of feedback on how implementations are done, adapting them to real market. Adoption of a standard is a social process that should be planned. It is sometimes easier for a specification to achieve successful adoption if it is presented as a set of small related formats, that each solve a concrete specific topic, than a monolithic format that tries to cover a large field.

Nowadays, assessment interoperability is being identified as one of the barriers to overcome to facilitate reusability in e-learning environments. Content reuse has always been identified as one of the big advantages of using standards. Assessment is a special case where content reuse makes even more sense [23]. Another important field of research is competence-based learning. Efforts are been carried out to clarify the link between learning content and competences. From the assessment point of view, ePortfolio is a tool of great interest to represent achieved learning outcomes and the evidences that sustained them.

UC3M is working towards the study of better standards and specifications in the context of the iCoper project [25]. As part of its objectives, iCoper will provide a Reference Model and mechanisms to ensure European-wide user involvement, cooperation, and adoption of standards in the educational framework. To accomplish this goal, the project will systematically analyse the specifications and standards available and in use, to draw conclusions on their validity. In the context of the iCoper project, an effort is under way to detect and solve the QTI interoperability problems by helping to complete the available tools to guarantee a robust exchange of assessment material. Related to assessment interoperability between some LMS (Moodle, .LRN and CLIX), some modules have been developed to enable this interoperability. These modules support importing and exporting assessment material between LMS and they are implementations of QTI 1.2.1. iCoper also deals with the link between IMS LD Units of Learning (UoL) and learning outcomes (including knowledge, skills, and competence), using HR-XML [26] as basis. On the other hand, the link between assessment and learning outcomes (through evidence records) is being investigated as well.

V. E-Learning Frameworks and Tools

It is well known that e-learning frameworks and tools are a critical asset for entities involved in the fields of learning, education, and training. These applications are of importance not only to bridge the physical gap between distant learners and the teacher, but to improve the learning experience and outcomes by providing support for other needs like collaboration, personalisation, adaptability, and new approaches of interaction with both learners and teachers.

The development of e-learning applications and platforms has been deeply affected by the present relevance of Web 2.0 tools and social networks that provide new ways for learners to collaborate in a more dynamic way. Systems such as LearnLand [27] and SciSpace [28], both based on the social platform Elgg [29], provide a high level of collaboration among the participants of a course through the utilisation of social tools. The provision of adaptation and personalisation form another area of interest in this field; as a proposal, [30] presents a way to personalise a virtual learning environment through the display of indicators within the LMS interface, while [31] describes an approach for providing an adaptive LMSs based on a standardised user model. In addition, another approach observed is to combine the use of more immersive user interfaces in combination with an LMS, an example of this is the Sloodle platform [32].

Current open research problems include the improvement of the level of adaptability of e-Learning platforms in order to enrich the learning experience. Another line of study is the use of non-traditional tools in the field of e-learning [33] that could lead to the interaction with external services, which requires an exchange of data providing the security and privacy that are taken as granted in any learning environment.

The UC3M group works with the .LRN framework, mainly through the provision and current maintenance of the GRAIL package, an IMS Learning Design RTE. Currently, this player is being enhanced with edition functionalities in order to provide flexibility at the deployment phase. Also, the accessibility has been improved. It has become a permanent requirement within its development. The research group has also provided an assessment package compliant with the version 1.2 of the IMS QTI specification; and by taking advantage of this compliance, current developments are taking place in order to provide assessment interoperability between the .LRN and Moodle frameworks.

VI. Adaptation, Adaptability, and Accessibility

Adaptive educational systems [34] in general appear in opposition to the "one-size fits all" paradigm for educational environments. When a learning experience is deployed, learners may have significantly different experiences depending on a variety of factors. The definition of an ideal adaptive system would be the one that provides to each learner the most appropriate environment. By environment we understand the context, resources, sequencing, evaluation, communication, support, and any other aspect that shapes a learning scenario. But as remarked in [35], adaptive tools have a poor presence in the LMS market mainly due to their lack of integration capabilities. Brusilovsky analyzes this issue in greater depth in [36] and points to the lack of integration as one of the reasons for this situation.

Thus, adaptation in general is a fairly wide and complex area, because it touches on the multiple aspects that affect a learning scenario. The proposed approach to deal with this complexity is to categorize the techniques for adapting a learning experience. The proposed categorization is:

1. Change the resources used in an experience, its order, its shape, delivery method, etc. depending on observations previously obtained from the user. We call this "Adaptive Choreography". For example, a learning experience may choose to deploy a group discussion or a set of individual exercises as the next activity in the class depending on some observations previously obtained from the experience.
2. Change the appearance of the platform (not the learning resources) to provide a more appropriate environment. In this category we would have techniques applied to change the appearance of a community, the auxiliary menus shown by default, changing the subscription policy in a forum, etc.
3. Adaptation in the context of accessibility. That is, the entire platform needs to change to any disability. For example, offer a larger font for the visually impaired.

The first category is intrinsically related to a learning environment, whereas the last two are generic to web applications. Any web-based application may need to adapt its appearance.

A. Adaptive Choreography

This type of adaptation has received an important push in recent years. The area of Intelligent Tutoring Systems offers a very rich landscape where numerous tools have been proposed. From the very early tools that were stand-alone and highly specialized in a context, today we can see proposals such as "KnowledgeTree" [36], where the emphasis is in integration with current LMSs using a set of "intelligent educational activities" with a distributed connection scheme.

A formal approach to adaptation has been taken by the IMS Learning Design specification [3]. This specification has been conceived as a formal framework to capture the structure and interaction in a learning experience including (a limited but) specific formalism to capture the interaction with services external to a LMS. Using Learning Design a so called "Unit of Learning" can be described including the set of resources that are to be used, the set of roles assigned to the participants in a learning experience (both staff and learners) and the interactions that are supposed to take place.

The specification is divided into three levels. Level A includes the description from a purely structural form of the set of resources needed by the learning experience. A UoL contains a "play", which is divided into "acts", and each act contains a set of learning activities. At any point in time, one act is "active". Level B of the specification is the one directly related to adaptation. A set of properties with different scopes (a role or set of users, a single user or a global property) can be defined and assigned values. Furthermore, a set of if/then/else clauses may be defined to change the appearance, visibility or structure of an activity based on the values of these properties.

Since the publication of its initial version in 2003, there have been several tools that appeared both in the authoring context [37, 38] as well as the execution context [38, 39]. In theory, a UoL captures all the requirements and pedagogical aspects of a learning experience such that it can be reused multiple times in different contexts.

In reality, adaptive learning with Learning Design has been shown to be fairly complex. Although this complexity could be assumed by instructional designers, its adoption threshold is higher than desired for other member of the teaching staff.

B. Adapting the platform appearance

Here we include the adaptation that needs to happen outside the learning resources of the educational experience more related to the platform in which they are hosted. Most of the current LMSs include a customization layer that allows rearranging the structure of the pages hosting a course to better adapt to the particular needs of a specific audience.

In Moodle [9] or .LRN [8] (to mention just two examples of open-source LMSs), the community page hosting a course offers a customization menu where the structure of the portlets can be re-arranged. This functionality is included in virtually any LMS. The importance of this adaptation is specially needed when deploying learning experiences with an audience with small experience in the use of LMSs or computers.

C. Accessibility issues in learning platforms

As in any other web platform, LMSs also face the challenge of adapting its content to people with different disabilities. Fortunately, this type of adaptation has been studied by international bodies such as the WWW Consortium, where the Web Content Accessibility Guidelines have been recently upgraded to version 2.0 [40].

In the context of learning, this problem becomes more challenging when creating learning content. An LMS may offer a perfectly accessible environment, but the learning resources that are usually produced outside of the LMS and created by teaching staff (not web designers) may not comply with these guidelines. In Section IX this problem is described in the context of authoring tools.

VII. 3D Social Virtual Environments for Learning

Advances in information and communication technology not only arrive ever more rapidly to our lives, but also produce a tremendous impact on the way we behave. Among the many consequences of these advances, we have a new generation of learners, so-called Digital Natives [41] with different patterns of work, attention, and learning preferences [42]. Digital Natives usually seek instant gratification, perform several activities concurrently, and behave efficiently in achieving their goals when motivated. Although Digital Natives are not characterized by being empathetic, they easily create new relationships within their own age group and mobilize people for a given purpose [42]. Thus, our main concerns are how to motivate students to learn and how to support teachers to apply instructional strategies adapted to this new generation of learners. In order to achieve our objectives, we explore technologies such as 3D virtual words, game design, social computing and e-learning.

A. Contributions from 3D virtual worlds

3D virtual worlds have a set of elements –also present in video games– that may help to seduce students into learning. The use of avatars as representations of students and instructors and the possibilities for customizing avatars, enhance the degree of realism and permit the subject to immerse him/herself in the 3D virtual environment for learning. The 3D scenarios also help to the sense of immersion and open up options of discovering new knowledge by exploring virtual worlds. The ability of avatars to interact with virtual 3D objects in collaborative environments offers new possibilities for the use of learning theories such as experiential learning, discovery learning and constructivism [43][71].

B. Contributions from game design

Games [44] use action instead of explanation and provide interactive content, therefore bring new ways of using teaching strategies [72]. Class activities such as presentation of a lecture can be done by an NPC (non-player character) representing a tutor or several NPCs playing situations that show students a given technique. NPCs can improve immersiveness by acting in plausible ways; their activities can be programmed using artificial intelligence (AI) methods. Deterministic AI techniques such as finite state machines, decision trees or even fuzzy logic are currently being used in video games and non-deterministic techniques such as Bayesian networks, neural networks and genetic algorithms are starting to be exploited in these games [45]. Our 3D virtual learning environments should find which kind of synthetic characters can be used and what AI technique can we apply for programming their behaviors.

Probably the main contribution of game design [44] is the use of rules to achieve specific outcomes to learning experiences, instead of using them with entertainment purposes. Rules are a crucial element in motivation in these virtual and social environments, they can be used to guide students towards acquiring new knowledge as well as for direct the community toward joint learning efforts.

C. Contributions from social computing

The new generation of learners demands social environments where they can explore knowledge by themselves, connect, communicate, and collaborate with other people in natural ways. Social incentive mechanisms must be used to encourage Digital Native's participation in collaborative tasks. Web 2.0 has opened new ways of communication and collaboration through techniques such as wikis, forums, collaborative tagging, and tag clouds that now must be adapted to 3D interfaces. Social visualization can relate academic performance to status in peer-group and also stimulate social comparison and competition.

D. Integration with learning management systems

A 3D social virtual environment is able not only to integrate a wide spectrum of instructional strategies that engage students in critical thinking learning activities, but also to motivate students, promote wide participation and make subjects easier to learn. Nevertheless, its impact as a pedagogical tool can be enhanced by embedding it in a Learning Management System (LMS) that manages the units of learning created in these learning environments.

E. Technological feasibility and work done

Open Simulator [46], Croquet [47], and Wonderland [48] are open source platforms that are suitable for creating collaborative 3D virtual worlds. They provide features such as avatars, NPCs, text and audio communication, sharing virtual objects and desktop applications and the possibility of transporting avatars between virtual worlds. From a previous study [49], we have decided to choose Wonderland as development platform, because it offers more possibilities for extensibility and has developed its immersive audio capabilities in a more advanced way.

A first collaborative experience was deployed. It consisted of a 3D virtual world, where avatars from several teams explored the world searching for the information a tutor asked them to find. The information was provided for NPCs that performed different dialogues for each learner team. The students were supposed to interact with members of other teams looking for missing information. Finally, the assessment consisted of a test to determine whether the students acquired the academic knowledge and social competences required.

VIII. M-LEARNING

With the steady improvement in the computational capabilities of mobile personal devices and the increasing needs for specialized and personalized training, new m-learning architectures and environments are being defined and used in different ways [50]-[54]. M-learning (and pervasive learning in general) scenarios enhance traditional e-learning scenarios by adding some new important dimensions to the e-learning process such as the anytime, anywhere space-temporal dimension. These new dimensions extend the e-learning concept to a new way of improving the learning experiences by the introduction of personal, context-aware, pervasive services. M-learning provides an "always on" user-context enhanced learning process. As Siobhan Thomas [52] states, m-learning leverages four components in the learning environment:

community driven learning, learning autonomy from the student point of view, location independency and context driven learning. It is therefore not surprising that some projects such as [55] are using mobile devices for e-learning. As Timothy R. Hill states in [56] "emerging mobile technologies hold great promise for educational institutions seeking to extend the learning experience to an increasingly nomadic and time-challenged student community, especially at urban campuses where both faculty and students typically commute to school and struggle to multi-processes work, study and family time and location demands."

Although there have been significant achievements both in m-learning theory and practice during the last decade, there are yet many open issues that need to be addressed. Some of them can be categorized as technology related, some as pedagogy related, while others can be associated to the motivational impact that the use of mobile devices and pervasive environments have on the student. Technological challenges in m-learning comprise the improvement in the computational capabilities of mobile devices, the increase in mobile network capacity, the improvement in programming languages for mobile devices, the use of embedded sensors, the integration of multimedia content and the ability to interact with smart environments. Pedagogical challenges encompass the use of mobile devices to support face to face activities, the use of mobile technology to reinforce traditional e-learning processes, the use of mobile devices as an always on channel to provide immediate and personalized feedback, the possibilities to control the learning process by learning using mobile devices, the use of a mobile device to support meta-cognitive activities or in social learning environments, or how to use the physical learning context in the learning process in either formal or informal learning environments. Motivational challenges include how to use technology to enhance the motivation of the students, how the increase in the control of the learning process motivates them and how the interaction with smart objects using mobile devices can also be a motivational factor for the student.

Among the different challenges previously mentioned, the UC3M group is currently focused on analyzing, synthesizing and proposing solutions for the use of mobile technologies as a "motivation factor", as a support framework of new learning scenarios in contextualized learning and for creating adaptive units of learning with flexible learning paths and as a support for meta-cognitive activities such as time management and process awareness. The group develops technological components and deploys them in real scenarios inside UC3M. The components use different types of networks to interact with the learning environment such as NFC and Bluetooth. The real experiments with students measure learning gains as well as motivational impacts.

The UC3M group is currently participating and actively leading some of the activities in two technology enhanced learning research projects: Learn3 and SOLITE. The Learn3 project is exploring and exploiting the synergies in the research work done by the UC3M e-learning group and the GTI group of the Pompeu Fabra University. Some joint m-learning experiments are being carried out with students in both universities gathering data of individual and collaborative interaction patterns with physical learning objects embedded in the student environment. The SOLITE project aims to align the research of some of the major e-learning research groups in Spain, Portugal and Latin-America. The UC3M group is defining and implementing m-learning activities both in Spain and Colombia, analyzing some of the motivational and learning impacts that the use of mobile devices may have on students in contextualized learning environments.

IX. Authoring and Application of Web 2.0 and Web 3.0 Techniques to e-Learning

At the early stages of e-learning, producing content was the same as publishing a web page or a document for download in the net. With the advances on web content, learning resources are now much more complex, and therefore, much more complicated to produce. The authoring paradigm has shifted from a one-person simple resource production scenario to a variety of production scenarios. De Freitas [57] divides these emerging scenarios into four categories: learner-authored content, practitioner-authored content, commercial and public-sector commissioned content and hybrid approaches.

The trend in authoring environments could be summarized as an evolution toward highly rich, service based, collaborative approaches. The "rip, mix, and burn" paradigm popularized by Apple has an ever increasing presence in the e-learning content production landscape also due to the large number of available resources with flexible licenses such as Creative Commons (see [58] or [59] for an example of such repositories). From this trend, several research venues and results are being considered, and most of them are derived from the ideas previously described in the context of deploying e-learning experiences.

The integration of external services is perhaps one of the most challenging ones. Re-using a resource such an image, a video, an animation, or a document are fairly simple due to the editing capabilities of most learning content production platforms. The challenge now is to raise the re-use of services to the same level of simplicity. Let us illustrate this problem with an example. Let's assume that an instructional designer is creating a course and as part of its pedagogical strategy decides to use a "blog" as a reflection tool (see [60] for a discussion on how useful a blog could be in a learning experience).

How is such "resource" included in a learning activity? The first approach would be to simply explain to students how to create a blog by themselves in the ever-increasing number of platforms available in the net. But this solution has a poor performance. Students should then relay to the teaching staff the location of such blog, and they would have a wide variety of structures, policies, etc.

The important observation is that a blog is a resource that has what we call an "instantiation" phase. In other words, as opposed to an image, a document, an animation that can be used by an arbitrarily large number of users with no impact, a blog needs to be instantiated as many times as required by the number of users. Learning Management Systems tried at first to provide these services internally, but they were quickly outpaced by highly specialized platforms available in the net.

What kinds of steps are required during the authoring phase to be able to use such a service during the enactment of a learning experience? Current research ideas propose to include a generic description of the service. Such description would include very generic properties such as "blogging tool", and a set of minimum requirements. For example: authenticated, restricted access to posts, etc. This would partially solve the problem of "including" such resource at the authoring phase.

But the real challenge is to manage the "instantiation" phase, which is no longer required when the instructional designer is creating the resource, but when the experience is being deployed. In this new scenario, this resource or service needs to be instantiated as many times as the experience is enacted, and if the service is in a per-user basis, as many times as users. In [7], this research avenue is explored and demonstrated with a service to provide questionnaires using Google Spreadsheets. The objective of the presented approach is twofold. On one hand, offer the integration of highly popular services emerging in Internet at the authoring phase to truly exploit their potential. On the other hand, achieve a tight integration between the learning experience and the service execution. By "tight integration" we mean that the learning experience should be able to gain insight on what happened inside the service to potentially react to it. This paradigm would truly capitalize in the use of these resources.

There are multiple possible scenarios that can take advantage of this paradigm. The closest one to current state-of-the-art tools is the use of forms for tests or quizzes. The service can be instantiated and the obtained results used to change the structure of an experience. Forums are increasingly present in e-learning, several research initiatives have been monitoring the activities in these forums to then deduce certain conclusions (see [61] for an example). If the service is integrated as described in this paradigm, these conclusions can be used to modify the structure of the remaining activities.

A second research venue being explored is the creation of reusable e-learning content in a distributed authoring environment. The approach combines the use of markup languages (such as docBook) and distributed source code management tools (such as git). The idea is to combine a learning object creation approach with a set of rules that take those objects and create a set of learning resources. The paradigm is being used in a few courses with a high number of content creators and the initial results are promising with respect to the distributed nature of the paradigm and need further improvement to lower the learning curve to use markup languages by the lack of visual tools.

Many developments have been carried out in relation with the Semantic Web since the paper by Tim Berners-Lee, Jim Hendler and Ora Lassila [62] was published in Scientific American, and many keywords have come up since then: Semantic Web, Web 3.0 [63], Data Web, Linked Data, … Many of these developments have found application for learning. The integration of learning technologies into the Semantic Web enables interoperability not only among e-learning applications and resources, but also with other Web entities, making more powerful interactions and services possible. Service-oriented architectures have been proposed, which make available Semantic Web methods for e-learning applications, such as for adaptive hypermedia [64].

The creation of ontologies and annotations for e-learning are necessary steps to build Semantic Web applications in e-learning. In this context, ontologies represent a formal knowledge modeling of different learning aspects. The generation of such ontologies implies an extra engineering effort, but they overcome the limitations of traditional e-learning systems [65]. A classification of the different types of ontologies for education can be found in [66]. While there are several works that explain ontologies that are not based on existing e-learning specifications covering different learning issues, on the other hand there are other works that try to adapt and convert existing e-learning specifications into the Semantic Web. In this line, there are RDF Bindings for IEEE-LOM, Dublin Core, IMS QTI, IMS LD, or IMS LIP.

Several applications have been built during the last years that enable to take advantage of the Semantic Web in e-learning. This includes searching applications like Courseware-Watchdog to perform searches based on meta-data [67], or adaptive applications like [68], which personalize learning contents based on reasoning over Semantic Web resources annotated according to defined educational ontologies, or tools like SMARTIES [69] for creating instructional designs based on pedagogical models and ontologies.

Although there is a wide community supporting research on Semantic Web applications in education and ontologies, there are several and important challenges at present. Firstly, even though there are promising works for the generation of automatic annotations and ontologies from text, the provision of easy to use or/and automatic tools that generate annotations and ontologies in Semantic Web formats for all the different aspects of e-learning is a challenge. These tools should provide ideally automatic and complete modelling for the knowledge domain through the ontologies, as well as correct annotations, being aware of the changes during the time.

The distributed vision of the Semantic Web also leads to the problem of compatibility among different ontologies and annotations among different systems. Some promising ideas have been proposed, but more effort should be made regarding this issue to be able to connect the different e-learning systems.

Another important open issue is the integration of a lot of existing traditional e-learning systems into the Semantic Web, so that the advantages of the Semantic Web can be taken. This implies an effort for defining ontologies, making annotations, adaptive rules, etc. according to the specific particularities for the different applications.

The UC3M group has contributed to the integration of existing traditional e-learning systems and services in the Semantic Web. In this direction, a new architecture for combining Semantic Web techniques with Intelligent Tutoring Systems has been defined, which combines traditional e-learning formats with Semantic Web ones, and a prototype for achieving adaptive hints according to the defined architecture has been implemented [70]. This development separates the adaptive rules for execution in a Semantic Web reasoner, while keeps the non-adaptive functionality for generation of hints in a traditional e-learning tutor.

CONCLUSION

In this paper, we have presented the many research lines carried out by the UC3M group of eMadrid in the context of e-learning. The field of learning has always profited from the advances in ICT. Presently, we have a wealth of new developments that are directly applicable. At UC3M, we follow several of them that in a synergistic way enriching one another.

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An Approach for Description of Open Educational Resources based on Semantic Technologies

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Abstract—**Open Educational Resources are accessed through the web, whose real setting shows an explosion in the use and development of tools and services based on Social Software. However, the growth of this data repository makes it difficult to find information of value, and reduces the possibilities of sharing and exchanging resources. Using semantic technologies to describe educational resources enables any agent (human or software-based) to process and understand its content (applying inference rules on more structured knowledge). Metadata standards can be used to annotate educational resources; they facilitate their interoperability and discovery. In this work, we propose, OER-CC ontology, for the description of Open Educational Resources under Creative Commons Licenses. This approach is based on standard technology and metadata standards. The ontology could be utilized in higher education institutions (and organizations) to facilitate sharing and discovery of their digital content. This electronic document is a "live" template. The various components of your paper [title, text, heads, etc.] are already defined on the style sheet, as illustrated by the portions given in this document. (Abstract)**

Keywords-component; formatting; style; styling; insert (key words)

I. INTRODUCTION

Open Educational Resources (OERs) initiatives promote their global exchange with the aim of increasing the human intellectual capacity. The principal idea of the movement toward Open Educational Resources is that knowledge is a public good where technology in general, and specifically Web, provides an extraordinary opportunity for people to acquire key competences in a knowledge society while they share, use, and re-use digital contents.

OER are teaching, learning, and research digital re-sources and tools (see **Figure 1**), available on the public domain or that have been released under an intellectual property license, that is, permit their free use, re-use or re-purposing by others.

The next level of educational technology infrastructure will need to use social tools and semantic technologies applied to the Web. The application of Social Web in OER projects has demonstrated that regular users can contribute content without specialist skills; any person can participate actively as an author in the Knowledge Society. By other hand, semantic Technologies enable the power of the semantic web for easy sharing, re-using and educational resources discover.

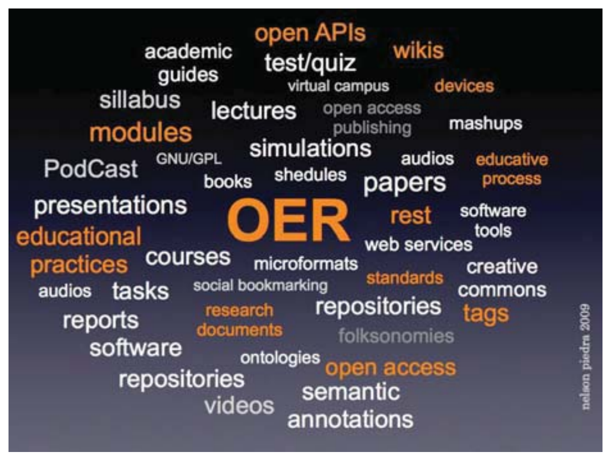

Figure 1. Open Educational Resources Map

In this paper, we propose, OER-CC ontology, for the description of Open Educational Resources under Creative Commons Licenses. This approach is based on standard technology and metadata standards. The ontology could be utilized in higher education institutions (and organizations) to facilitate sharing and discovery of their digital content.

This document is divided into 3 sections. The first section introduces the models and OER drivers and we put forward options for incorporating semantic technologies in OER description. Next, development process of OER-CC ontology is described; at each stage of ontology creation we argue the choice of each standard, tool and applied language. In the last section, we describe the recovery process of knowledge represented in ontology; several queries were designed to obtain information about the properties of the resources generated in the Computer Science School (CSS) of the

Technical University of Loja (UTPL, *Universidad Técnica Particular de Loja* - Ecuador).

II. Description of Open Educational Resources (OERs) by mean of Metadata and Ontologies

The Open Educational Resources Initiatives are based on the **Open Access (OA) movement**.

Declarations of support for OA have been developed to accelerate efforts to promote open resources, technology and teaching practices in education. The Declaration of the Budapest Open Access Initiative [1] (BOAI, 2002) was among the first to strongly promote the open and free access to academic and research contents.

In the same way, importance of OER has been promoted by international and national organizations initiatives. Some of these **initiatives** are: Massachusetts Institute of Technology (MIT) in 2001 with its project OpenCourseWare and the OCW Consortium [2], projects from OECD's Centre for Educational Research and Innovation [4], UNESCO Initiative through International Institute for Educational Planning [5], the Open University's Open Learn Project[1], Universia MIT OCW – Spain[2] and IEEE-Signal Processing Society[3] will be work with the open-access repository project Connexions. Other initiatives can be found on the Wiki of the UNESCO OER Community[4].

OER Projects can be classified according to model (funding, technical, content and staffing) used to ensure their sustainability. Downes in [3] describes each of the models.

In this paper, we focus on staffing models, that is, by the degree to which participants could actually help with resources. Considering this point of view, there are two models: producer-consumer and co-production [4] (we can find a comparison between them in the Wiki community project, WikiEducator[5]).

In **producer-consumer models** (or user-producer), an institution or consortium develop materials and release courseware under an open license, which can be reused by other providers. Within this group the MIT OpenCourseWare can be considered.

Co-production models encourage open and unrestricted participation, aimed to leverage the benefits of mass-collaboration and the principles of self-organization. This model, can promote the collaborative production of common resources.

The co-production strategies to OER production can be deployed using *Social Web* tools. The Web 2.0 or Social Web is focused in the contents, relationships and knowledge but not specifically in technology. As Will Richardson [6], [7] writes: "The good news for all of us is that today, anyone can become an all life student. (Yes, even you.) Those technologies are easy to use in a way that was not possible in the past".

[1] http://openlearn.open.ac.uk
[2] http://mit.ocw.universia.net/
[3] http://ieeecnx.org/
[4] http://oerwiki.iiep-unesco.org/
[5] http://wikieducator.org

The use of wikis is a good example of transition from static and restricted web sites to social and collaborative participation (co-authors). O'Reilly refers to Wikipedia as "a radical experience of confidence" [8]. Wikipedia, blogs and other tools allow the user to publish and then the community determines the relevance and pertinence of the content; mistakes are solved by social correction and with the support of content configuration management (version control).

The core strength of the social software is its easy use, however a OERs co-production model based on this kind of services have some weaknesses; Redecker in [13] identifies the main risks, barriers and obstacles to the implementation of Web 2.0 into teaching and learning practice. Besides those points, we also believe that one of the greatest difficulties to adopt this approach is that the use of social tools is generating an impressive growing in the quantity of contents that are available in the internet. This situation is hindering the organization, retrieval and resources interoperability and its "intelligent" processing is required. Using semantic technologies we can provide a more explicit meaning to information, so that computers can understand and generate new knowledge by applying rules of inference to a better structured knowledge

A. *Incorporating semantics in OER Production*

These days, the use of semantic technologies and applications development of the Semantic Web (SW) in the learning context, are the focus of researchers, organizations, universities and consortiums.

Semantic technologies will automate or semi-automate certain educative tasks trough "synergy between human and machines" (see **Figure 2**). Thus is explained by Gruber in [14] "Clearly, there are different roles for people and machines. People are the producers and customers: they are the source of knowledge, and they have real world problems and interests. Machines are the enablers: they store and remember data, search and combine data, and draw mathematical and logical inferences". With the incorporation of web semantic technologies in processes of creation, storage, retrieval and educational resources remix we expect a reduction in workload of those who run the learning process.

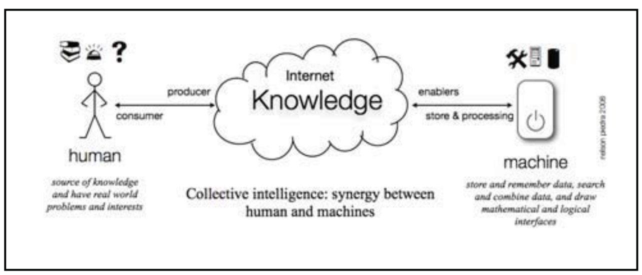

Figure 2. Synergy between human and machines

The Koper's study [15] showed application areas of the SW in education, he talk about will help to educators to perform some of their tasks such as settings, assessment and management and courses administration. We also think that the Semantic Web will enable to:

- identify more easily resources with particular properties or that have a kind of specific relationship with others;
- use of semantic rules, it can be a good support for interpretation and argumentation of several issues;
- suppliers of educational contents that use semantic technologies improve the administration, exchange and integration of resources with other information suppliers;
- bear a great potential of providing a robust and extensible base for emerging Social Web applications; interchange, distribution, and reuse of OER can be greatly facilitated by the infrastructures that the Semantic Web offers.

To achieve these objectives, educational resources should be described by a standard schema in a way that any agent (human or software-based) can understand and processing its content

1) Metadata Standards for Educational Material

Al-Khalifa and Davis as said in [24] "Metadata standards are formal specifications used to semantically annotate educational material of any king. They have been developed to support both machine interoperability (information exchange) and resource discovery by human users". Some metadata schemes allow the description of resources in XML, RDF, RDFa, or even OWL.

For the learning materials "these various standards and specifications have been developed to meet different requirements and to support the needs of different communities" [16]. Three are most recognized metadata standards:

- The IEEE LTSC (Learning Technology Standards Committee) developed IEEE LOM[6] (Learning Object Metadata).
- The IMS GLC (Global Learning Consortium) proposes IMS Learning Resource Metadata[7].
- Dublin Core Metadata Initiative[8].

The structure proposed by these standards is similar; each one has categories and each category contains a set of metadata. Depending on application, we can choose a subset or extend[9] the set with more metadata (the out-come of this adaptation process is called "*metadata application profile*"). Given the effort required to describe an educational resource using each characteristic proposed by those standards, we could create an profile for describe OERs, considering the particularities of this type of resource, such as:

- Some projects are based on social software, there-fore, metadata about the social tools, type of re-source and resource annotations (using social classification systems, such as, folksonomies) are required.
- Open educational resources are licensed under copyleft licenses such as Creative Commons (CC) or GPU/GPL, therefore, metadata about licensing is needed to determine what is permitted, required or prohibited in a work.

2) Ontologies

According to Gruber`s definition [11], an ontology specifies the conceptualization of a specific domain in terms of concepts, attributes, and relationships [12]; also it should be expressed in a *formal language* "so that a given ontology expression can be interpreted and processed" [18]. Unlike other knowledge structures (e.g. library classification or thesaurus), an ontology allows applying logic, inheritance and other issues [17].

In 1997 emerged the first **language for ontologies** SHOE[10] (Simple HTML Ontology Extensions), so far some languages have been proposed to be more complete and less complex languages than their predecessors. Nowadays the languages most used are RDF and OWL; one of limitations of RDF is that it is not expressive enough to represent complex ontologies, while that OWL extends the possibility of using logical expressions to describe complex concepts and relationships.

The **modeling of domain knowledge** can be done us-ing traditional paradigms and tools, UML (Unified Modeling Language) or database technologies. But as stated Gomez et al. [19] "…the formalisms used to model the domain knowledge and the languages that implement these techniques limit the kind of knowledge that can be modeled and implemented", i. e. "only allow the representation of lightweight ontologies". Consequently to modeling of large or complex domains have been proposed several approaches that allow us develop ontologies ("heavyweight ontologies") based on Artificial Intelligence (AI) formalisms; so we have better control over the vocabulary and the semantic. In [19] a comparative study between these three paradigms can be found.

There are several **methodologies** for building ontologies, two of them could be regarded as more mature a) METHONTOLOGY, proposed by Gómez-Pérez et al. in 1996; and b) On-To-Knowledge, proposed in 2001 by Staab et al.

Regardless of the methodology used to create the ontology, its design should be guided by the Gruber's principles: clarity, coherence, extendibility, minimal encoding bias and minimal ontological commitment; the idea is to ensure the "knowledge sharing" [21]. To fulfill these criteria, **ontology evaluation** should be performed at the same time as the development-oriented activities. Different type of evaluation could be made [23]: a) *Syntactic evaluation*, to check languages specification b) *Semantic evaluation*, focused on detecting if the ontologies have inconsistencies and redundancies c) *Lexical evaluation*, it refers to the vocabulary used to represent concepts and domain relationships. Other

[6] http://ltsc.ieee.org/wg12
[7] http://www.imsglobal.org/metadata/index.html
[8] http://dublincore.org
[9] According to level of granularity and required interoperability

[10] www.cs.umd.edu/projects/plus/SHOE

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issues related to evaluation are presented in the Brank's et al. [25] paper.

B. Related Work

We have found several works that involve the development of ontologies for a specific issue of e-learning or to modeling knowledge related to a specific problem.

1) Ontology for e-learning system

Ghaleb et al. in [12] developed an ontology for web-based e-learning system of Qatar University. End-user can annotate learning resources by means of Web form; the system converts this information to a set of RDF statements using the RAP API (Semantic Web toolkit for PHP developers). According to the authors "the ontology can be used for adaptive learning to retrieve the context of a course and to structure the contents". Their model includes a service of simple semantic search.

This work cannot be reusable in OER domain because it isn't metadata standards-based (or there isn't information) and the ontology model hasn´t been published.

2) Application ontologies for assembling learning objects

Santacruz in [26], [22] put forward *OntoGlue*, "an ontology-based mechanism for assembling learning objects". In order to assemble two learning objects, the requirements of one must be covered by the competencies of the other. The problem resolved by OntoGlue is the semantic comparison (considering that one requirement and one competence can't be syntac-tically equal, but the semantics is the same) among concepts, since mappings between ontologies are established. The standard LOM is used to describe ELOs (Electronic Learning Objects) although an extension that has been included.

3) Metadata Standards for describing Objects and Learning Resources

For semantic representation of Learning Objects. Fermoso et al. in [20] put forward the ontology LOM2OWL[11], its structure allows to describe LOs using IEEE LOM standard. Later, we will refer to this work.

For description of Learning Resources. Brown and Thomas explain in [9] metadata approach within the OER project "The Open Polytechnic of New Zealand". They created an application profile that contains necessary elements to ensure metadata interoperability "with both a national and an international audience", thus, 15 metadata was chosen of those 5 belongs to Educational Category. However, this work doesn't consider projects social software-based neither the licensing issue.

For description of works licensed under Creative Commons (CC). In 2008, CC published the metadata standard ccREL[12] (Creative Commons Rights Expression Language), it that aims to "make licensed works more reusable and easy to find". To date ccREL metadata, as encoded using RDFa or XMP.

[11] http://www.cc.uah.es/ie/ontologies.html

[12] http://wiki.creativecommons.org/CcREL

III. DEVELOPMENT OF OER-CC ONTOLOGY

In this section, authors introduce details dealing with the implemented ontology to model the OER and CC domains. Thus, research team tried to achieve the following main goals: (i) to describe OER and CC resources using a common vocabulary by users and producers, i.e., an implemented ontology offered to students and lecturers within an educational context respectively, and (ii) to automate execution of tasks for selected domains such as information retrieval using semantic techniques.

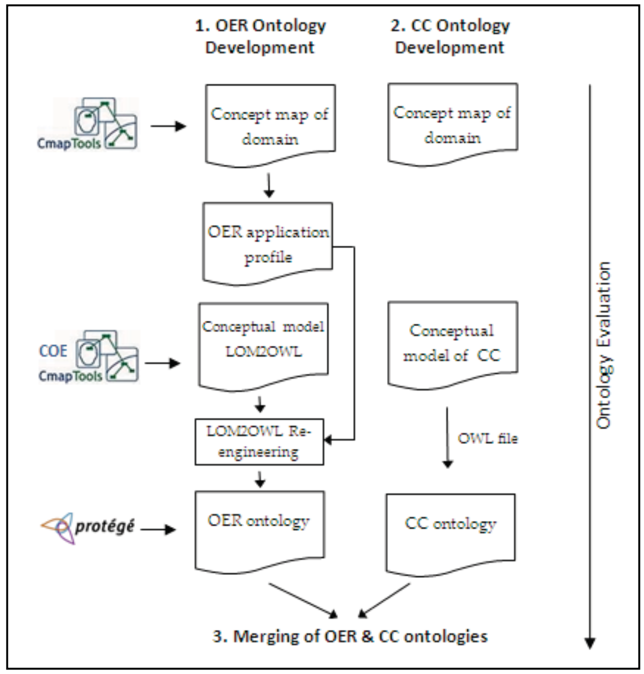

Figure 3. Process and tools for ontology development

A. Process and tools to build OER-CC ontology

Then, development process of our OER-CC ontology was divided into three general phases:

1) OER ontology development. At this point, we started with an initial ontology (LOM2OWL[13]) adapted to the metadata requirements for OERs (based on IEEE LOM).

2) CC ontology development. In this case, CC ontology was designed using METHONTOLOGY [19] guidelines.

3) Merging of CC and OER ontologies. Finally, we unified concepts, terminology, definitions and constraints from the two source ontologies.

B. Development process

As introduced before, development process was based on METHONTOLOGY [19] guidelines. This method proposes an ontology building life cycle based on evolving prototypes. That is, it allows adding, changing, and removing terms in each new version (prototype). Next, figure 3 depicts the development process and used tools through each phase respectively.

[13] http://www.cc.uah.es/ie/ontologiaLOM2OWL/LOM2OWL.owl

Therefore, we started the development process creating concept maps for both knowledge domains respectively. For this purpose, we depicted main points of OER-CC ontology with a general study of references to describe metadata of selected domains. As a consequence, we evaluated some well-known references to describe OER metadata like IEEE-LOM [30] and Dublin-Core (DC) [31]. At this point, we understand that IEEE-LOM introduces enough metadata to characterize our educational purposes for this work. In addition, IEEE-LOM was used because we think that it includes large amount of structured metadata into different categories, allowing greater semantic flexibility for our selected domains. Another important issue was that it is a leading standard within e-learning environments [16] usually.

Then, all metadata associated with CC licenses was represented considering the ccREL standard [10] which provides information related to Licenses Properties, e.g., permissions, prohibitions, requirements and general metadata. Once we had decided how to describe metadata, we selected well-referenced tools to model the OER-CC ontology successfully. Concretely, we used the following:

- **CMaptools** [28] was used to represent and intern-connect both knowledge domains, i.e., OER and CC respectively. In addition, **Cmaptools Ontology Editor** [14] (COE) was used for constructing, sharing and viewing modeled ontology based on CmapTools. Besides, this allowed preparing OER-CC ontology to be modeled using **OWL**[15] language.
- **Protégé** [29] was used to implement our ontology formally. For this purpose, all prior results were imported to this ontology editor. Then, we used **SWRL**[16] to provide deductive reasoning capabilities and **SPARQL**[17] to retrieve the educational resources metadata.

Each tool and language was applied at different stages of process.

Additionally, each prototype of OER-CC ontology was validated through evaluation items like: (*i*) Syntactic evaluation, by mean of Pellet reasoner[18] and syntax checker used for this work, (*ii*) Taxonomy evaluation, at this point we validated standard rules in taxonomies like inconsistency, incompleteness and redundancy in concepts respectively. Once we finished the development process successfully, we were ready to deploy OER-CC ontology. Therefore, next section introduces details that give preliminary evidences of our contribution in this work.

IV. OER-CC Ontology Instantiation and Retrieval

Then the formalization and implementation activities are carried out, in this last section, we attempt to provide a piece of the true potential of ontologies use to represent domains in the context of Education and particularly to describe OERs, i e.

- The machines can understand and interpret meaning of educational content, thus facilitate or automate execution of certain tasks, such as, accessibility or retrieval with the contents of both domains.
- Users and OER producers[19] can use a common vo-cabulary to describe their resources; it enables to reuse and to share application domain knowledge.
- Represent a metadata structure through ontology; it will enable interoperability among different do-mains (vocabularies). This promotes accessibility and OERs sharing between universities and organizations around the world.

One of the ways we use to demonstrate that potential is defining and executing queries and inference rules on OER-CC ontology to retrieval and to exploit its knowledge. Before discussing the results, we explain the filling the ontology with resources metadata produced in a higher institution.

A. *Instantiation process and tools*

Once the ontology is built, the process of ontology popu-lation starts, and then it allows extracting relevant information from the resources hosted by ontology. The population process "consists in creating a knowledge base containing instances of the ontology concepts and instances of the ontology relations" [19].

This process can occur in 3 ways, depending on the level of automation is required or that it can be applied. This process can occur in 3 ways, depending on the level of automation is required or that it can be applied.

1. *Manual.* This mechanism may be viable when we have a small number of instances for each concept and it can be done through ontology development tools and tool suites; they provide basic support for the ontology population so that ontology developers can create instances with their ontology editors [19].
2. *Semi-automatic*, applying automatic learning techniques on sources of unstructured or data semi-structured.
3. *Automatic*, creating specific applications (using ontology management APIs) to generate in-stances from structured data sources and directly insert them in each concept.

For the OWL ontology population, Protégé offers certain plugins.

- DataMaster[20], to import schema structure and data from relational databases into Protégé.

[14] http://coe.ihmc.us/groups/coe/
[15] http://www.w3.org/TR/owl-ref/
[16] http://www.w3.org/Submission/SWRL/
[17] http://www.w3.org/TR/rdf-sparql-query/
[18] http://clarkparsia.com/pellet/

[19] The role of users and OERs producers change depending on adopted production model. In a user-producer model, students consume re-sources and institutions generate them; while a co-production model anyone participant (including students and self-learner) can contribute to creating them
[20] http://protegewiki.stanford.edu/index.php/DataMaster

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- XML Tab[21], to import an XML document into Protégé, creating a set of classes and instances in a knowledge base which correspond to the entries in the XML document.
- Excel Import[22], to import content and classes from Excel or CSV files, it available so far only for Protégé 4.0.

In all cases, the data source must be in a structured format and classes are created according to this structure. When the ontological model has been implemented a process is required to move instances from the new classes to existing classes.

B. *OER-CC Ontology Instantation*

To instantiate the OER-CC ontology, we considered some resources generated in the Computer Science School (CSS) of the Technical University of Loja (Universidad Técnica Particular de Loja[23], UTPL-Ecuador).

UTPL are using social software for knowledge management, learning and OER development based on a co-production model. From 2008, the School has opened completely all the training courses of Engineering free of charge; this has enabled the exchange of experiences internally and with other academic units.

A manual process has been developed to populate the OER-CC ontology with the CSS' educational resources, because Protégé plugins import schema structure and data from structured sources (unlike what is required in this work since we already have the model). Concretely, those resources are videos and keynotes authored by teachers and students basically. In addition, they are available on youtube[24] and slideshare[25] of the School's channels also. Furthermore, instantiation dealing with CC domain was considered using different types of Creative Commons Licenses with jurisdiction in Ecuador[26].

C. *Information Retrieval*

As introduced in section 3.2 we used SPARQL language to retrieve knowledge represented at our OER-CC ontology. Thus, we developed some queries to retrieve information, e.g., properties of OERs and CC licenses.

What is more, our initial results show that our OER-CC ontology has been deployed successfully, i.e., using metadata from initial instantiation of educational objects.

Some queries were designed to extract information from OER-CC ontology, geared mainly to determine its use in tasks of recovery, accessibility and OERs re-mix.

[21] http://protegewiki.stanford.edu/index.php/XML_Tab
[22] http://protegewiki.stanford.edu/index.php/Excel_Import
[23] www.utpl.edu.ec
[24] http://www.youtube.com/eccutpl
[25] http://www.slideshare.net/eccutpl
[26] http://creativecommons.ec/

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Table I and **Table II** list some competency questions that can be answered by the ontology. SPARQL panel of Protégé was used to run queries, the next step is to develop or integrate applications (software agents or web services) that implement the above activities.

As shown in **Table I**, one of the advantages of using OER-CC ontology and the IEEE-LOM standard is that we can complete information for each resource metadata in various languages and thus facilitates multilingual search.

TABLE I. COMPETENCY QUESTIONS FOR OERS RETRIEVAL

More specific searches can be constructed by applying filters (assembling different types of combinations) on different OERs properties. Multilingual search. If multilingual descriptions of metadata were specified
Competency questions
¿What is general information of an educational resource (title, description, keywords, and other metadata)?
What educational resources are labeled with a particular word? Such questions are especially common in a co-production model in which multiple annotators can add, in a simple way, tags to each resource. The tags could be used to improve search results as proposed in [27].

TABLE II. COMPETENCY QUESTIONS FOR ACCESIBILITY AND REMIX

• We can exploit the information on licensing, contribution and attribution to facilitate accessibility and OERs re-mix
Competency questions
What are the resources created by a particular contributor and what type of contribution have done?
What are the direct contributions of a university in the OERs production and what are indirect contributions through their teachers / students?
Who should be given attribution and under what conditions we can make use of OERs?
What are all contributors (individual and organizational / institutional) of a specific OER?
What kind of licenses we use to can generate educational resources in a country and under what conditions these can be remixed?
How can access (URI or URL) to an OER and how it can display (depending on the type of resource)?
What educational use and in what context we can use an OER?

Next, we introduce a implemented query (to answer the question: what are the direct contributions of the UTPL in the OERs production and what are indirect contributions through their teachers/students, see **Figure 4**) within OER-CC ontology.

These queries results confirm that a short-term improvement in information retrieval task can be achieved considering educational resources generated at the Computer Science School of the UTPL.

```
SELECT DISTINCT ?entity ?contributor ?organization
                ?oer ?contributionrole
WHERE
{
  {
    ?entity rdf:type :Person.
    ?entity table:isContributingEntityOf ?contributor.
    ?entity table:hasOrganization ?vcorganization.
    ?vcorganization table:entityName ?organization.
    ?contributor table:isContributorOf ?oer.
    ?contributor rdf:type ?contributionRole.
    ?contributionRole rdfs:label ?contributionrole.
    FILTER REGEX(?organization, "Tecnica Particular de Loja" , "i")
  }
  UNION
  {
    ?entity rdf:type :Organization.
    ?entity table:isContributingEntityOf ?contributor.
    ?entity table:entityName ?organization.
    ?contributor table:isContributorOf ?oer.
    ?contributor rdf:type ?contributionRole.
    ?contributionRole rdfs:label ?contributionrole.
    FILTER REGEX(?organization, "Tecnica Particular de Loja" , "i")
    }
}
```

Figure 4. Query for retrieval UTPL contributions

CONCLUSION

In this work, we have given initial evidences that machines could understand and interpret semantic meaning of educational contents.

As a main contribution, we have implemented OER-CC ontology to model knowledge dealing with OER and CC domains respectively. Therefore, we have been able to inference knowledge using OER-CC ontology, i.e., thorough instantiation and classification of educational objects respectively. About work in progress, research team continues working to improve OER-CC ontology deployment. Currently, we are involved with more methods to promote accessibility according to OER user requirements; e.g., the content of an educational resource could be ranked within the OER-CC ontology according to student / lecturer profile respectively.

Furthermore, this work has enabled us to implement ontologies from concept maps (process used to generate CC ontology). With the support of easy-to-use graphical tools (as Cmaptools) could massify development of ontologies, with the additional advantage it may include domain-experts.

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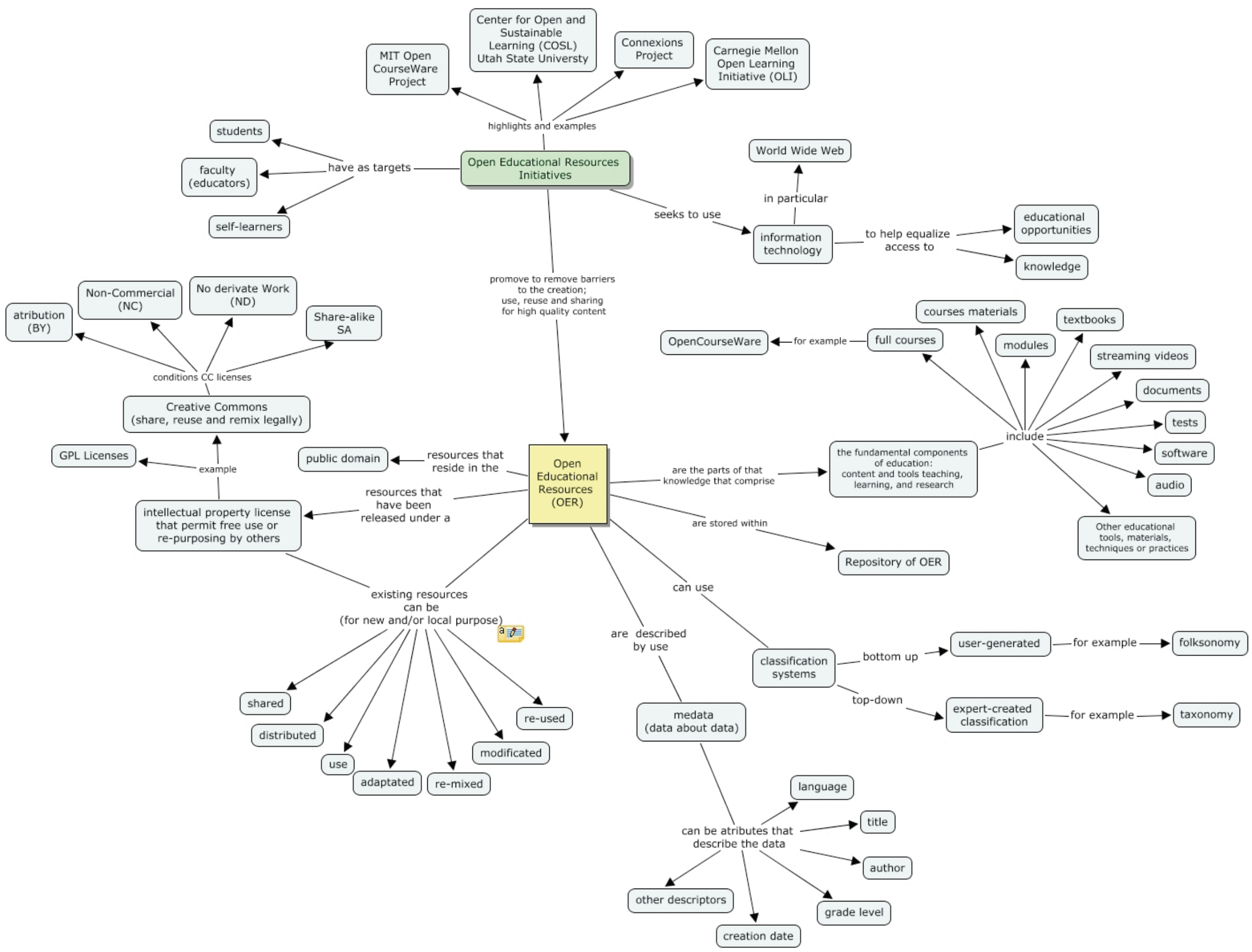
ANNEX 1 CONCEPTUAL MAP: Open Educational Resources Knowledge Domain



<e-Adventure>

Introducing Educational Games in the Learning Process

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Abstract—**Within the last years educational games have attracted some attention from the academic community. Multiple enhancements of the learning experience are usually attributed to educational games, although the most cited is their potential to improve students' motivation. In spite of these expected advantages, how to introduce video games in the learning process is an issue that is not completely clear yet, which reduces the potential impact of educational video games. Our goal at the <e-UCM> research group is to identify the barriers that are limiting the integration of games in the learning process and propose approaches to tackle them. The result of this work is the <e-Adventure> platform, an educational game authoring tool that aims to make of video games just another educational tool at the disposal of the instructors. In this paper we describe how <e-Adventure> contributes to the integration of games in the learning process through three main focuses: reduction of the high development costs of educational games, involvement of instructors in the development process to enhance the educational value, and the production of the games using a white-box model. In addition we describe the current research that we are conducting using the platform as a test-bed.**

Keywords-<e-Adventure>; educational games; authoring tool; LAMS

I. Introduction

Instructors, parents and public authorities are astonished by how dropout rates have grown in education at all levels for years. This alarming trend suggests a drastic decrease in the motivation of the students towards learning.

Several hypotheses have been formulated to explain this controversial issue. In this line, several authors like Prensky [1] argue that there is a clear disconnection between students' expectations and what they receive in the classroom. According to Prensky, current students are *digital natives*, people used to interact with rich interactive digital media such as computers, mobile devices or video game consoles; this differs from the typical pedagogical strategies in terms of content and interaction [1, 2].

To tackle this issue, a deep reform should come to the educational system, updating the content and interactivity used to support learning. One of the proposals is the use of video games and other kind of interactive technological content. Actually, the application of games in education is a trend on the rise. There is a belief that video games have potential to enhance the learning processes in multiple ways. One of the most frequently discussed is the ability that games have to increment students' motivation towards learning as they are able to capture their attention and keep them engaged and immersed [3, 4]. Other interesting traits of educational video games is that they provide immersive in-game worlds that can be explored freely by the students, promoting self-directed learning [5], their short feedback cycles with perception of progress [6], or their relation to constructivist theories and support of scaffolded learning [7].

This interest in the use of educational video games laid the basis for the <e-Adventure> project [8-10]. <e-Adventure> is a platform that has been developed by the <e-UCM> research group at the Complutense University, and its main aim is to facilitate the introduction of the games in the learning process. Nonetheless, to achieve this goal several barriers have to be tackled first. In this paper we describe the main problems that are preventing a more general adoption of educational gaming, according to our own research experience. Between the most relevant issues we find the high development cost of video games, the difficulty of involving instructors in their development, and the complexity of using the games in traditional pedagogical approaches. After that we describe how these issues have been addressed in our proposal, the <e-Adventure> platform.

All the research conducted in our group about educational games, and the effort invested in pushing the development of the <e-Adventure> platform forward has turned <e-Adventure> into a solid product that is available for download and ready to use[1]. Thus <e-Adventure> is not only the result of our past research, but also a great test-bed where we are implementing our new work on educational games. In this paper we also include a discussion about the main research lines we are working on.

Therefore this paper is structured as follows. Firstly, in section II we briefly discuss the main limiting factors for the

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[1] <e-Adventure> can be downloaded from the next website: http://e-adventure.e-ucm.es

general adoption of educational games. After that, in section III we summarize the approaches that we have proposed to tackle them, and how they have been implemented in the <e-Adventure> platform. Later, in section IV, we describe the main research lines we are working on and how we are integrating them in <e-Adventure>. Finally some conclusions are presented in section V.

II. Towards the Introduction of Games In the Learning Process: Open Issues and Barriers

As stated in the introduction, video games seem to have potential as learning tools, but their use in real scenarios is limited by multiple factors that span all over the product life, affecting the design, implementation and deployment phases. In this section we discuss, according to our opinion, some of the more relevant issues that affect educational games in these three stages.

A. Issues at the Design Stage: Balancing Educational Value and Entertainment

One of the main challenges of developing an educational game is the achievement of an adequate balance between entertainment and educational value [7]. Both factors are indispensable for the success of the game. If the students do not have fun playing they will finally quit the game and all the investment would be useless. However, if all the efforts are focused on the fun-factor and the educational value is left aside, the game would have little impact on the learning outcomes of the students. Therefore the development of educational games adds, to the difficult task of designing game elements that are fun and engaging, the challenge of achieving educational value [11, 12].

To ensure that an educational game has educational value we need to effectively involve instructors in its development. On the one hand instructors are the domain experts, who can check that the accuracy of the knowledge ‘stored’ in the game is appropriate. On the other hand, instructors have the crucial responsibility of applying the games in the real learning scenario. Nevertheless current game development methodologies limit the involvement of instructors due to the technical background required. As a consequence, there is a need for the creation of specific development methodologies that take into account all these issues and propose effective mechanisms to get instructors involved in the development process.

In addition, educational games have their own needs that may differ from more traditional, entertainment-driven developments. In this sense it is very important to choose a game genre that suits these needs. There are several studies that have analyzed what are the more suitable genres for educational applications. Authors like Dickey argue that story-driven genres, like Interactive Digital Storytelling or *point-and-click* adventure games can better fit the needs of educational gaming for a broader set of domains as they promote content instead of plain action [13-16]. For instance, the presence of elements such as a slow pace, reflection, study of the environment, and problem-solving make point and click adventure games relevant from a pedagogical perspective [17].

B. Issues at the Production Stage: the Costs

One of the most drastic disadvantages of applying video games in education is their high development costs. High-profile commercial (non-educational) video games have often budgets of several million dollars. For instance, as analyzed in [18], a high percent (40% approximately) of the educational game developments active or recently finished in 2005 were expected to cost more than $100K. Arguing in the same line, the study described in [19], estimates the development costs of commercial video games in the range of $10M-$25M for 2008.

Those estimations are a barrier for the introduction of video games in the educational process, as it is almost unfeasible for most educational organizations to develop their own educational games if no external funding is available. Obviously that issue virtually narrows the applicability of educational games to pilots and research projects, impeding a general adoption.

The lack of reusability of video games is another hindering factor. Video games are usually sold and distributed as *black boxes*: self-contained, closed products that are rarely scalable to other domains and contexts. This lack of flexibility reduces the potential of video games for learning as instructors need to adapt, reuse, maintain and share their materials and those developed by others (actually these are frequent behaviors of instructors).

C. Issues at the Deployment Stage: Delivery and Assessment

Finally, some of the main barriers that hinder the adoption of educational games are related to the complexity that they introduce in the learning process from the instructors’ point of view. In this sense, the actual use of educational games is limited due to several factors.

On the one hand, there are inconveniences concerning the delivery, distribution and deployment of the games. Video games are complex pieces of software that are usually distributed in CD or DVD and that require some installation on the player’s system. In addition, while a lecture typically requires a blackboard and some pieces of chalk video games require up-to-date computers and controlled environments which are seldom present in schools [20]. Moreover, even when this kind of equipment is present in the schools, they usually lack the staff preparation and/or the time required to organize educational gaming sessions.

On the other hand, it is burdensome for the instructors to track and assess the learning experience. As games are usually *black boxes*, from which extracting information is arduous, instructors need to plan carefully how they are going to evaluate the learning outcomes and achievements of each student (usually through time-consuming debriefing sessions).

III. The <E-Adventure> Platform

The result of the research carried out in our group on educational gaming is the <e-Adventure> platform for educational game development. In this section we discuss the solutions that we have proposed for the issues discussed in section II and the more relevant features of <e-Adventure> that implement them.

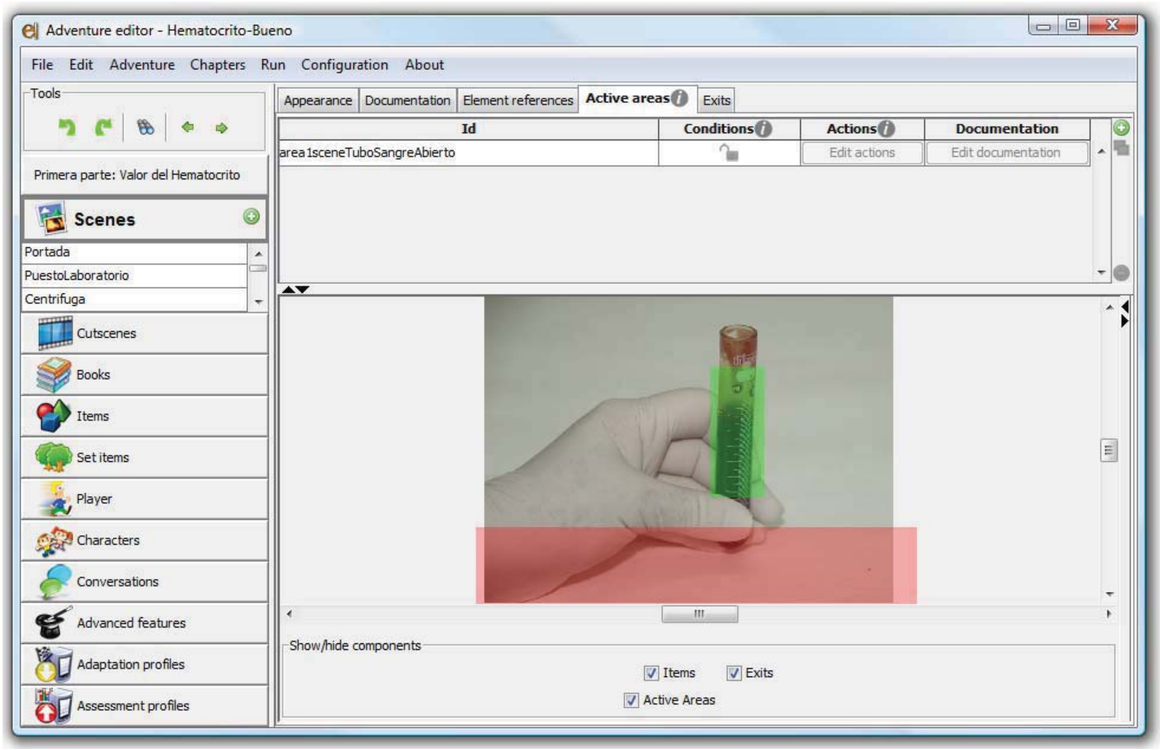

Figure 1. Screenshot of the <e-Adventure> game authoring tool.

A. Increasing the Educational Value, Decreasing the Development costs

As aforementioned, some game genres have traits that make them more suitable for educational purposes than others. In this line, story-driven games can be good educational tools as they improve the problem-solving skills and promote reflection instead of action. Thus the <e-Adventure> platform is focused on the *point-and-click* adventure game genre (in the style of games such as *Monkey Island*© or *Myst*©).

This genre is not only interesting because of its high educational value, but also because the development cost of these games is minimal. Besides, in order to broaden the potential domains of application of <e-Adventure> the platform supports the creation of two different types of games taking adventure games as a basis: *third-person* and *first-person* games. While the first type of games has been applied in concept-intensive domains like History [21], the second has been useful in the development of games for teaching procedural knowledge, for instance, in several medical applications [22, 23].

In addition, an appropriate game genre is not the only enhancement of the educational value that <e-Adventure> includes. As discussed so far, the level of instructors' involvement in the development of the games is a sound prerequisite to achieve a good educational value. <e-Adventure> aims to allow instructors to develop their own educational games, or at least contribute in their production by following two strategies.

First, along with the <e-Adventure> platform, we have proposed a development methodology for the development of story-driven educational games [24]. This model allows the cooperation of multiple roles (e.g. storywriters, programmers, artists, etc.) of different technical background in the development of the games. In this manner the methodology supports the integration of instructors in the process as non-technical staff, trying to make sure that "a good story never ends in a bad game".

Secondly, <e-Adventure> includes an instructor-oriented game authoring tool (see Figure 1.) which does not require any kind of technical background [25]. The authoring tool allows instructors to create their own games as no programming is required, and also contributes to reduce the development costs. Moreover, even if some instructors may find creating entire games from scratch too ambitious, this approach at least allows those instructors to open the games developed by others in order to review the contents, make minor modifications, adapt games for different contexts, etc., allowing them to contribute in the development process.

Furthermore, the authoring tool also promotes reuse as it has been developed in compliance with standards and specifications of the e-Learning field, allowing in this manner the exportation of the games as Learning Objects (LO) [26] that can be shared in content repositories (e.g. the AGREGA LO repository developed by the Spanish ministry of education).

B. Facilitating Deployment and Assessment: Integration with e-Learning Environments

Once the games are already created, <e-Adventure> also helps to make their use in the actual learning scenario easier. The main strategy that we have followed to address this group of issues relies on the integration of the games in e-Learning environments like *Moodle™, Sakai™* or *Blackboard™*. In our opinion this approach brings numerous benefits.

As we previously mentioned, <e-Adventure> games can be packaged as Web-based Learning Objects. This facilitates their distribution through e-Learning environments to the students' computers without requiring any installation (only a web browser is needed) [27].

Secondly, once the <e-Adventure> games are deployed on the e-Learning environment, the platform also enables a communication channel between game and server [28]. Through this channel the instructors can extract information about the progress of the student in the game, the goals that are achieved, etc., and have it submitted to the e-Learning environment to be attached to the students' profile [10, 29]. For instance, instructors could identify using the authoring tool game situations that have a relevant meaning from a pedagogical point of view (e.g. a specific puzzle is not completed and some knowledge is not unveiled), define a score for those situations and get that score sent to the e-Learning environment just as any other kind of test for the student. Hence <e-Adventure> games are not *black-boxes* but *white-boxes* where instructors are aware of what happens during the execution of the game.

IV. Open Research

As discussed so far educational gaming is a trend that has attracted the efforts of different researchers in the last few years. Nevertheless, in spite of all the work done, there are still different open issues to be solved in order to achieve the final goal of turning video games into feasible, affordable learning tools. We are thus currently exploring several lines of research and testing them within the <e-Adventure> platform, including mobile game-based learning and adaptive and accessible educational games. In this section we will focus on two specific projects: the integration of <e-Adventure> in the LAMS e-Learning environment (section IV.A) and the development of a story-driven game authoring tool (section IV.B).

A. Integration with e-Learning Environments: LAMS

As discussed previously, our approach to ease the integration of educational games in the learning process heavily relies on the integration with e-Learning environments. Although lot of research has already been conducted, resulting in the integration of <e-Adventuture> in systems like Moodle™ using standards and the Learning Object Model, we are still exploring new approaches.

As part of this research line we are working on the integration of <e-Adventure> with *LAMS* (Learning Activity Management System), an open source e-Learning environment [30]. Like other e-Learning environments, LAMS manages all the features of the online courses in a centralized way for all the roles involved. But the most interesting feature that makes LAMS different is that it also allows teachers to create *activities sequences* (that is, to model the learning flow and the activities it includes).

With the easy-to-use sequence authoring tool that LAMS includes instructors can define the learning flow by graphically combining out-of-the-box activity tools (e.g. chat, forum, question and answer activities, etc.) that LAMS integrates. Moreover, instructors can define branches in the sequence by defining conditions on the outcomes of some tools, allowing alternate paths for different students or groups and depending on their achievements. Finally, LAMS also provides a monitoring mechanism that allows modifying the flow of the sequence while it is being executed, giving the teacher more control of the educational experience.

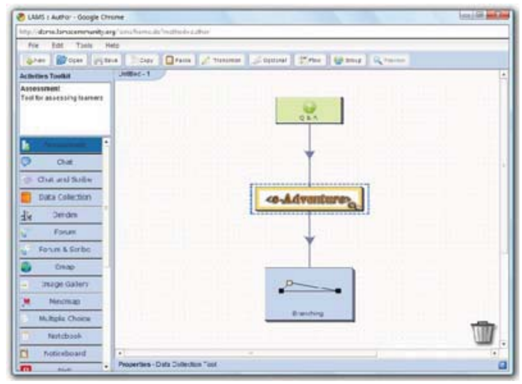

Figure 2. The activity sequences autoring tool in LAMS. A sequence of activities including an <e-Adventure> game that is used for branching.

Our aim is to make of <e-Adventure> another 'out-of-the-box' LAMS activity tool (see Figure 2.). Therefore instructors could upload their own educational games to the system and integrate them in their activity sequences. In addition, <e-Adventure> games will be able to receive the outcomes of other tools as inputs (e.g. the score) and produce their own outputs (e.g. score, time played, etc.). This opens a lot new possibilities that are interesting from a pedagogical point of view. For instance, instructors could define branches in their sequences using the outputs produced by <e-Adventure> games. In this manner instructors could provide activities to reinforce learning if the outcomes are not the expected. Moreover they will also profit from the high interactivity of the games to know more about the students and provide them more adequate activities. Finally, the inputs received from the sequence could be also used to make internal branches in the game according to the history of the student, allowing the adaptation and personalization of the game-based learning experience for the needs of each student.

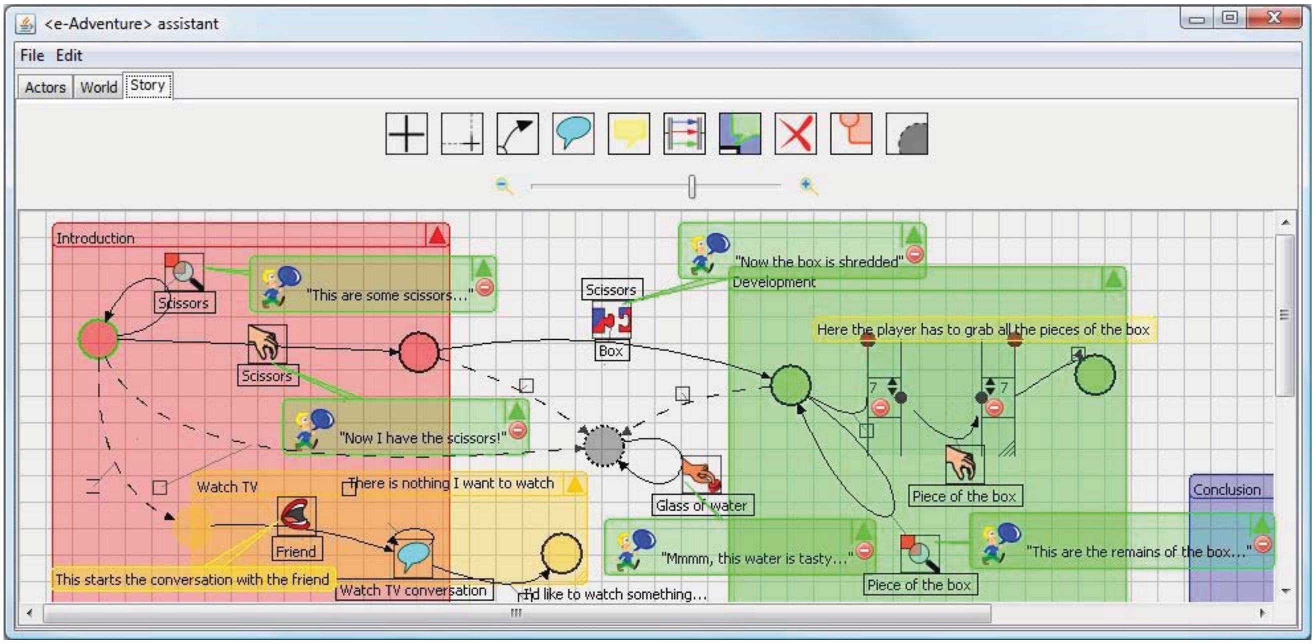

Figure 3. Screenshot of the story-driven authoring tool (prototype)

B. Easing the Authoring of the Narrative Thread: A Story-Driven Authoring Tool

One of the design issues discussed in section II refers the impact that a powerful narrative thread may have on the educational value of educational games, as discussed by other authors. Nonetheless the production of a good storyboard for an educational game is not an easy task, given that to the burdens of making the story engaging and fun we add the difficulty of achieving the adequate educational value.

That is the motivation for one of our current main research lines. Our goal is to develop a graphic authoring tool that simplifies the production of a good storyboard for an educational game in terms of engagement and educational value. Besides, we will integrate this new tool with the <e-Adventure> editor, where the description of the games and the story lays hidden behind, and intertwined with the multitude of different elements that make up the game. As a consequence of this integration, <e-Adventure> will be an innovative development framework that integrates multiple tools for each stage of the development process of the games, including not only a content-based authoring tool but also a story-driven one.

The story-driven editor will use a visual modeling language to describe the game. In this representation there are visual elements to represent the different states that the narrative thread of the game can have and the possible actions the player can take (see Figure 3.). Therefore the storywriter can visualize and edit the narrative flow and how the interactions of the player affect the course of the story.

Working over the representation of the storyline described above, the game author will be able to define automatic assessment behavior, which will ease the addition of educational value to the games.

Additionally the new authoring tool will also include a feature to model, in a separate graphic sheet, the 'virtual world' of the game. This will facilitate the establishment of a bijective relation between the story and the places where it takes place. Using these new tools the initial description of the games is streamlined, leaving details to be dealt with in a later step. This is also, in general, a good practice in game design methods [13, 31].

The design of this new authoring tool is based on ideas introduced by experts in other areas (particularly Interactive Digital Storytelling) and systems used to create interactive computer stories in the early 90s [32-34]. Besides, it introduces new elements that make it easy to guide the user in the creation of new games by reusing patterns, applying methods developed by specialists in storytelling and game-making and creating recommendations based on the structure of the story [4, 35].

V. CONCLUSIONS

In this paper we have presented the research we are conducting at the <e-UCM> group at Complutense University in educational gaming. Our aim is to identify the barriers that are preventing the generalization of educational video games and propose solutions from a technical perspective. Between the relevant issues that we have identified so far, some of the most important are the problem of balancing educational value and entertainment, the high development costs, and the complexity that games introduce in the classroom dynamics.

To address these issues we have developed the <e-Adventure> educational gaming platform, which aims to reduce the development costs while keeping high quality standards in terms of educational value and entertainment. Using <e-Adventure> it is easier for instructors to create, adapt, share and use their educational games in their courses. Thanks to all the efforts invested in developing the platform, <e-Adventure> has reached the state of 'product', going beyond a 'research prototype'. This allows us to conduct new research on educational gaming and test it within <e-Adventure>.

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Abstract—**Libre (free, open source) software brings new opportunities, but also new troubles, to the education experience. It provides a great deal of new tools that can be used unexpensively and easily. On the opportunities side, it enables customization and adaptation to special needs, and full reproduction of educational experiences without depending on a budget for expensive software licenses. But it also brings the troubles of charting a new territory, maintaining applications in a demanding environment, and finding ways of adapting to specific needs.**

In this paper, we introduce these issues by analyzing a practical case study which has been run in real classes during several years: the contribution by students to a "planet" ("blog of blogs") with topics related to an educational subject.

Keywords-open source; free software; libre software, education, blogs, planets;

I. Introduction

Blogs, also known as weblogs, are websites containing notes in inverse chronological order, which are publicly accessible over the Internet. Usually, they offer visitors the possibility of commenting entries [1] [2] .

Blogs have become mainstream during the last decade, dealing with topics ranging from politics to technology. They are run with a great variety of objectives, from activists trying to publicize their opinions to corporations trying to become closer to their customers. Blogs have also been used for educational purposes, for example as a source of information for students, or as a way of presenting assignments and summaries of class work. Currently, most learning management systems include blogs as an integral subsystem.

Planets are websites which aggregate (syndicate) content from different blogs as if they were a unique blog. The name comes from Planet[1], a libre (free, open source) application that is widely used in the libre software community. Such sites are commonly found for libre software projects, aggregating contributions from developers who write in their own blogs. The way planets work is very simple. Blogs usually offer their content in some XML-based format (RSS, Atom...), known as the *feed* of the blog. Feeds can be accessed by means of a public URL. The planet software downloads feeds corresponding to the syndicated blogs and aggregates them in inverse chronological order as if all the stories would belong to a single blog. In some cases the planet only shows the title and a part of the body of the original blog entry (a small paragraph or a few lines), offering the possibility to read the rest in the original blog, thus avoiding that long stories would render the planet webpage unreadable.

To identify the authors of every single post, an avatar of the author is used, which is commonly known as a "hackergotchi". Hackergotchies help to identify the author of a contribution in the planet, since planets usually contain texts from various authors, which is much less common in regular blogs.

Planets help in the creation of a community, as the mostly personal views of contributors are grouped in a single location for each project. Informal, and sometimes personal or not-project related information is shared among the members of a project, offering new points of view and stimulating discussion and innovation.

Although planets have been used by the libre software community for some years now, there is little use of them in the educational community. However, blogs have been widely used for various educational purposes. Stephen Downes [8] has reviewed the history of weblogs in education, and has identified the five main uses of blogs in this area:

- managing classes;
- posting materials;
- holding discussions or seminars;
- publishing summaries and comments on readings;assessing tasks assigned to students who maintain their own blogs.

Downes also describes some of the problems of using this technology in education. One university setting where blogs have been used is in the lyrics. Professor Barbara Ganley has extensively documented his experience in this area for years [4].

1 http://www.planetplanet.org

In the field of Spanish-speaking education, Gewerc describes the subject "New Technologies applied to Education", parf of the degree of Master at the University of Santiago, where blogs are used [5]. This paper refers to some of the educational initiatives -written in Spanish- that use blogs, both in the field of higher education as in high school. In [7] the experience of creation and use of blogs carried out during the 2003/2004 course by teachers and students of the subject “Audiovisual Design” at the School of Communication in the University of Navarra (Spain) is documented. Within the scope of the experimental sciences, from the end of the last decade, Grupo de Sistemas y Comunicaciones (GSyC) at the Universidad Rey Juan Carlos (Spain) has been continuously using blogs in all their classes as a mean of communication among students and between students and professors, especially to assist in the development of practical subjects of Computer Engineering and Telecommunication Engineering. As an example of this experiences, [6] describes the use of Zope / Squishdot in a group of subjects.

This article presents a teaching experience of e-learning based on the use of a planet of blogs that has been augmented with functionality that allows students to evaluate the stories of their classmates. To do this, students had to create a blog for writing stories with content related to the subject. The contents of all the student blogs were linked into a planet, the central location where they can be read and commented. The experience presented refers to six subjects of non-technical degrees. Of these six subjects, one was on-site and the other five were complete distance learning experiences. All courses were related directly or indirectly to computers, information technologies, computer networks and free culture, but none of them was purely technical. The total number of students who have participated in them is around 350.

The structure of this paper is as follows: next, a methodology for the use of a planet of blogs in education is presented. Then, some hints on our experiences are pointed out. Finally, some conclusions are drawn.

II. METHODOLOGY

The procedure of this activity is as follows. Each student has to create a blog specific for the subject. All student blogs are linked from a centralized location, the planet. Students will be able to positively rate entries from blogs of their peers that they believe provide useful information for the subject.

Each student should create a blog where entries include notes related in some way with the subject (explanations, comments, anecdotes, etc.). Blogs are individual. Professors should put special emphasis on advising students that blogs should have original content, and not simply copied and pasted information from other sites. They are also instructed on how it is always good practice to reference or display external news by using links, and to comment personally the content they present. Some other hints related to writing texts for the Internet are also provided, with particular attention to how to do it for blogs. In this sense, long entries are discouraged, HTML is briefly introduced and some guidelines on the visual aspect of the blog are commented.

To create a blog, students can use one of the many free platforms that offer this service and that allow the contents of the blogs to be exported in any of the following formats: RSS 1.0, RSS 2.0 or Atom. Example of these are Blogger, WordPress, Bitacoras.com, LiveJournal or Blogia, but many other exist on the Internet. Students will then have to aggregate their blog to the planet by entering the following information:

- The URL of the blog
- The name or pseudonym of the student
- The e-mail address of the student

The resulting form can be seen in Fig. 1:

Fig. 1.- Registration form.

Once properly registered, the blog will automatically appear on the planet.

Every blog must have a minimum number of entries at the end of the semester. That number of entries has to be calculated according to the number of students, because if the required frequency is very high the total number may be too big to be followed properly by students. In the learning experiences, weekly and biweekly frequencies have been tested, so that at the end of the semester there are at least a dozen (or half a dozen) news per student.

The votes received by the blog of a student, coming from peers will be considered for the evaluation of the activity.

In addition, and to foster that students rate their peers on a regular basis, voting entries from other blogs will also be taken into account. In this way, both writing in their blog as well as reading the planet accounts for the final mark. Teachers can assess additional items positively, in general, once the activity is finished. This may include aesthetic considerations (configuration of the blog, proper use of a blog-suitable style, etc.) in addition to the quality of the content.

Each student will have a number of points each week that can be distributed among the entries of blogs of his peers. To do so, at the bottom of each entry on the planet there is a link "Vote me!" through which you can rate that specific entry. The votes of peers and teachers will be taken into account when assessing the subject.

From the experience in several subjects, we have noted that the number of votes per student and per week should be at most a quarter of the total number of blogs syndicated in the planet. The rationale for this lies in the fact that if students have too many votes, discriminating between good and bad entries is not possible. Giving students a number too small, on the other hand, discourages reading the planet as once they have given out all votes, they may stop reading more stories. For the usual class of 40 to 50 students, five to ten votes per week is in general an acceptable number. Teachers may vote the entries they like, although in their case they have an unlimited number of points.

Fig. 2 shows how the planet is structured. On the right, after a brief introduction and some links to the page with the registration form and the page with the rules of the activity, the stories authored by students are listed in reverse chronological order. Each story has its own box, which shows the name of the author, the text of the post and two end links. The first link, "Vote me!", allow students to vote the story, while the second, "Read the full entry", leads to the website blog, since for space reasons entries on the planet are shown only partially (only the first 250 characters are displayed in this example).

Meanwhile, on the left side of the window there is some information about when the planet was last updated, and the list of syndicated blogs. The planet is automatically updated every hour, which means that every hour the software of the planet takes the feeds of the syndicated blogs and generates the list of stories in reverse chronological order that can be seen on the right.

If a student decides that a story of a colleague on the planet is worth one point, clicking on the link "Vote me!" takes him to a page where you are asked to fill out the form shown in Fig. 3.

Fig. 3.- Voting form.

III. Teaching Experience

The authors have been able to test the methodology in several university courses and postgraduate degree subjects. The problem areas found were as follows:

- Creating the blog. As the subjects involved in this experience were mainly targeted to students of non-technical degrees, this was for many of them the first time they faced the world of blogs. To mitigate the problem, we encouraged their peers with advanced technical knowledge or who were more familiar with technology to devote their first entries to how to set-up and manage a blog.

- Identification of the feed and registration at the planet. Once the blog has been created, the identification of the feed, including its URL, is a problem for many students. This may become a main blocker, since that information is necessary for registration. The greatest difficulty is in fact the concept of feed itself, which is not easy to understand at first for many students. Therefore, teachers are encouraged to show the difference between the feed (intended for machines) and the main blog page (intended for humans) and to show some examples.Avoiding impersonation when voting. To prevent anyone from voting on behalf of a peer, we had to think of a way of avoiding it. The mechanism we finally implemented was very simple: when you vote, you must indicate your e-mail address. With every vote a voucher of the vote is sent by email, stating that the vote has been stored and urging the receiver to contact the teachers in the case that the vote was not given by him.

- Detection of deceptive voting. The fact that students themselves can assess their peers can lead to situations where two or more students may use fraudulently the voting system, voting indiscriminately. It may happen that a student randomly distributes votes without reading the entries, thus obtaining a good assessment in reading. To avoid these situations, we have designed and implemented a voting analysis software that using data mining techniques and social network analysis identifies "abnormal" situations.

IV. Conclusions

This article has presented a teaching experience of blogging by students of non-technical degrees in which they participate in the evaluation of the contents provided by their peers. We have seen the procedure followed in this activity and have highlighted the experience of deploying it in several universities for several subjects.

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Automatic Guidance Tools for Enhancing the Educative Experience in Non-Immersive Virtual Worlds

Preliminary results from project V-LeaF

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Abstract— **The interest of the Education community for Virtual Reality (VR) technologies has increased in the last few years due to their attractive 3D immersive worlds and facilities to provide a good environment to develop educational and collaborative tasks. However, these technologies present three main drawbacks: (1) a high cost in terms of hardware and infrastructure, (2) a high level of technology knowledge, and usually programming skills, is required to build up an educational and functional platform, and (3) once the educational platform is available for use, the educators are limited to the functionalities provided by the platform used. Our previous experience, designing and deploying a VR educational platform, named V-LeaF, showed that non immersive platforms (close to the gaming 3D platforms) provide High School educators and students with an attractive environment in which many features of the teaching/learning experience can be explored. However, this technological strength appears as a potential weakness feature of our platform when is used by high school students. Serious problems to maintain the student attention in this kind of domains have been detected, so the educators must employ time and dedication to ensure that students are really attending and acquiring the educational concepts scheduled. In this paper we describe an initial set of software tools developed (for both teachers and students) to solve the previous problem. An eye-gaze monitorization device allows teachers to focus the students' attention. A forms-based recommender system allows students to guide teacher's activity.**

Keywords: Virtual worlds; Virtual reality; Education; Recommender systems; Opensim

I. INTRODUCTION

The application of Virtual Reality to education requires a specific infrastructure, such as hardware in the classroom, or wearable devices, and its economic cost can be high as it is the case for immersive technologies. In this paper we show a software infrastructure capable of emulating hardware devices and communication between these devices. Specifically, we have created virtual versions of immersive virtual reality teaching-oriented devices, most of them based on monitoring the activity of students and teachers.

For example, students' eye-gaze monitoring allows us to provide teachers with a virtual device capable of displaying the "attention-level" of students. Eye-gaze is a key factor to check the comprehension level of students in immersive virtual environments [1] [2], but the effects of this factor in non-immersive environments (such as V-LeaF) has not been checked yet.

From our previous experience using Virtual Worlds environments with High School students, under the project V-LeaF[1] , we detected problems to maintain reasonable attention levels in the students. To monitor students by using immersive devices does not look to be an operative and scalable solution. For this reason a new system has been designed in a particular VR educational platform that allows in a non-intrusive way to monitor the attention of the student. The non-intrusive characteristic is essential if the educators need to provide a free environment for the student, improving their cooperation and collaborative skills. On the other hand, automatic recommendations and information about the attention level of the students must be provided dynamically to educators.

The paper is structured as follows: section II provides a brief description about our VR educational platform and other related work. Section III describes the automatic monitoring system. Section IV gives details about the scheduled experiments to be carried out by using the proposed system and, finally, Section V shows conclusions and future work.

II. VIRTUAL REALITY EDUCATIONAL TECHNOLOGIES

A. Underlying technology

The proposed monitoring and recommender system has been created by using the V-LeaF platform [3] [4], an infrastructure initially oriented to high school teachers and students, aimed at enhancing the teaching and learning experience respectively.

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[1] See http://this.ii.uam.es/vleaf

V-LeaF uses the infrastructure provided by OpenSimulator [2], an open source project which allows **developers** to extend the base functionality by means of pluggable software artifacts named *modules*, such as RealXtend[3]. An in-world programming language oriented to **users** is provided, aimed at providing functionality to in-world objects. In such a way, V-LeaF extends functionality by allowing teachers to use (and, eventually create) in-world objects with a given functionality. By using this approach the adoption barrier is lowered, by allowing teachers to create teaching devices for the V-LeaF community. Objects created under this contributory philosophy can be modified and extended by other teachers, evolving according to the users (teachers) needs.

The V-LeaF project site provides teachers with manuals and tutorials in two levels: basic and advanced. The basic level provides information about how to use the teaching devices, not requiring technical skills at all. The advanced level provides material about the in-world programming language (Linden Script Language, or simply LSL), the development of teaching-devices such as the ones described in the basic level, and the V-LeaF installation guides to allow teachers to create their own V-LeaF virtual worlds. The skills required for the advanced level have been minimized. Most of this material was requested and supervised by high school teachers participating in the first V-LeaF experiments carried out during the 2008-09 course.

B. *Related Work*

Second Life (SL) raised the educators' interest towards virtual worlds due to its high power/easy-of-use ratio. For the first time, the application of virtual worlds to education is in teachers' hands, and many studies involving high school teachers have been carried out [5-8]. Some of the authors participated in the creation in SL of a virtual version of our academic institution (EPS-UAM) [4] in 2008. Although we realized the possibilities of this environment, we noticed that this virtual world could be improved in several aspects:

- To create objects in SL requires renting a parcel. This is an administrative task with an economic cost.
- The parcel is not isolated of the rest of the SL world. While students attend a course, other users can get in this parcel and interact with the students, which may interfere in the lessons course.
- The lack of parental control (as a "black" list of locations not recommended) discourages this world for under-18 students.

Although the SL parcel's access-control policy can be customized, the skills required to achieve this task are high for average users (teachers). V-LeaF provides teachers with a web application to organize students in groups, thus simplifying this management task (see Fig. 1). V-LeaF students belonging to a given group are bounded to a specific "island", and the access policy prevents students from leaving the island and prevents students in other groups from getting into the island.

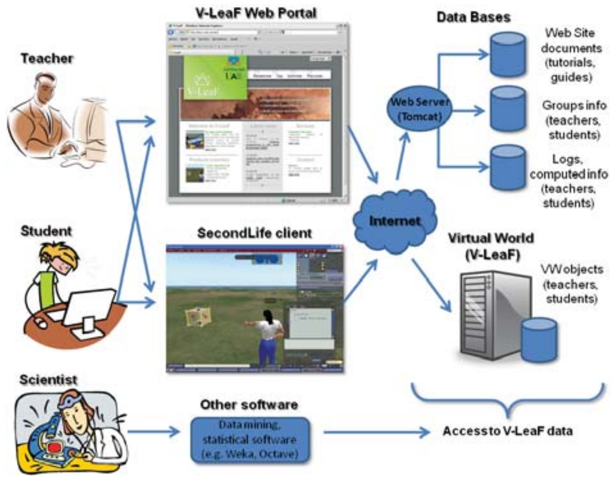

Figure 1. The V-LeaF infrastructure.

OpenSim can be regarded as a non-commercial version of SL. OpenSim is free source, and can be downloaded and installed for free. The compatibility with SL is almost complete: the in-world programming language (LSL) is portable, objects are interchangeable between these worlds and even the communication protocol between clients and servers are compatible. An enthusiastic community of developers provides new software modules to extend the basic functionality (e.g. to allow new in-world programming languages). Our aim is to create a similar community but oriented to teachers, not to professional software developers, focused on teaching devices and teaching techniques.

An additional benefit of using open software is that the functionality of the platforms can be modified. This task requires advanced skills (e.g. management and development of C# software projects), and is not intended for teachers, but it is the added value of V-LeaF. For example, V-LeaF can monitor students and teachers silently. However, SL or the "non-hacked" OpenSim (on which V-LeaF is based), warn users when they are going to be monitored.

III. V-LeaF Virtual devices in action

There is a need for evaluative systems to measure the success of virtual environments by monitoring students, teachers, contents an technologies [9]. Having this objective in mind, the following is a list of relevant virtual devices developed by our team. The selection of these devices was the result of a requirement analysis made by high school teachers that attended the first V-LeaF experiments carried out during the academic course 2008-09.

A. *Monitoring the students eye-gaze*

As we pointed out previously, the importance of eye-gaze in learning is well known. For example, there is a relation between teacher's eye gaze and student's attention and contents comprehension [1]. Another interesting experiment from this

[2] See http://opensimulator.org

[3] See http://www.realxtend.org

[4] See http://www.ii.uam.es/esp/sl/index.html

study states that the location of the student in the virtual classroom has a direct effect in the student results. These experiments were carried out in immersive environments in which each location changed the student view of the teacher, privileging locations close to the teacher and with a direct vision (face to face).

3-D multiuser virtual environments (3-D MUVEs) [10] such as V-LeaF, are found familiar to students due to its similarity to modern 3D games. Although these environments do not provide students with the realism of immersive technologies, both approaches share the importance of social aspects of digital learning environments [11]. For example, the theory of Transformed Social Interaction (TSI) [12] divides the potential of real-time transformations during interaction in three groups:

- *Social-Sensory abilities*. These transformations complement human perceptual capacities. For example, virtual devices can monitor student's activity to be reported to the teacher in real time. This is the most relevant aspect exploited in V-LeaF.
- *Self-representation*. A given avatar can be rendered (transformed) in different ways. For example, it could be the case that some students learn better with smiling teachers, while others improve their learning with serious teacher faces. Although the virtual world provided by V-LeaF is the same for all participants, there is an exception: student's view point. Unlike immersive environments, in MUVEs it is important to distinguish between the avatar's view point and the user's view point. For example, although the student's avatar is quiet facing to a given object, the student can observe this scene from any direction by moving his/her own "camera". This fact can be exploited to suggest users to move their cameras to a privileged position, without having to move their avatars.
- *Social environment*. The perception of the rest of participants can be modulated to filter, for example, distracting gestures of participants. This aspect cannot be modified in V-LeaF.

The virtual device named "Students Monitor" (SM) comprises the teacher monitor and a bracelet that each student must wear on his/her wrist. Each wrist monitors the student eye-gaze (indeed the position and direction of his/her camera) sending the information to the teacher monitor. This monitor shows a graphical representation of the location of each camera (see Fig. 2), in which color and blink are visual indicators of the student visual focus. The monitor has a default configuration, but this can be configured by the teacher, with parameters for (only the most significant are shown):

- *List of relevant objects.* By default it comprises only the teacher, but this list can include other objects relevant for the students learning process, such as blackboards or workbenches.
- *Maximum gaze inattention time.* Number of seconds that the student can lose visual attention. When this limit is exceeded, the student blinks in the teacher's monitor.
- *Refresh frequency.* Number of times per second that the teacher's monitor request data to each student's bracelet.

All the information managed by the Students Monitor is available for researchers and teachers through a web application in which raw data are provided as CSV files. Some basic analysis is shown in the web application pages.

The teacher's monitor can be attached to the user's view to avoid indiscreet students' views. This mechanism, provided by OpenSim is also used by the virtual device shown in the next subsection.

Figure 2. Teacher's monitor of the "Students Monitor" virtual device. This monitor is a virtual object that can be attached to the user's view (usually the teacher's view). In this example it is attached to the upper left corner.

B. *Evaluating the teacher activity*

One of the student demands is a mechanism to anonymously evaluate the teacher activity. To this end, a virtual device named "Teacher Evaluator" was developed by our team. This device comprises a Questioning Object attached to each student's view (see Fig. 3) and an Evaluator Object attached to the teacher's view (see Fig. 4). As all the objects are attached to the participants' views, the anonymity is guaranteed for students and teachers.

The Questioning Object prompts students with questions one at a time and it is configured externally through a web application. These are the most relevant parameters:

- *Evaluation frequency*. Number of minutes between questions. There is a random delay to avoid the synchronization of the students' responses.
- *Questions*. This is the list of questions that will be presented to the students during the teacher's activity. Although there is a default set of generic questions, these questions can be adapted to the subject domain to provide a more precise result. The current implementation only considers mono-answer questions in order to simplify and minimize the student's response time.
- *Answer tolerances*. Each answer has a tolerance associated. This tolerance is the percentage of students that can answer this question. When this tolerance is

exceeded, the Evaluator Object warns the teacher, who will reformulate or retell the conflictive topic.

The Evaluator Object can be configured to relax the warning conditions for different situations. The conditions in a 10 min. talk may be different to the conditions for a 50 min. talk.

As for the Students Monitor, the information recorded by this virtual device is exported as a CSV file for additional analysis and a basic summary is displayed in the web application pages.

Figure 3. Questioning Object (upper left corner) in action. A question with 5 possible answers is prompted to the student. The student can provide an answer or cancel the request.

Figure 4. Teachers' Recommender system in action. The Evaluator Object displays the recommendation in the teacher's view centre. Information collected from the students' questioning objects is used by the recommender to guide teacher's activity in real-time.

IV. Scheduled Experiments

This section shows a set of scheduled experiments to be carried out by high school students during the course 2009-2010. These experiments exploit the virtual devices described in the previous section.

A. *Related to monitoring students' eye-gaze*

By using the Students Monitor, we have designed the following experiments:

1) Test the Bailenson results. Bailenson reported the existence of privileged positions (close and facing to the teacher). These results were obtained in immersive environments, and we should check that this effect is observable in 3D-MUVEs such as V-LeaF. If this effect was observed the utility of an automatic recommendation system for students could be evaluated. This system could suggest the better user's view (camera position) to attend a teacher's lecture.

2) Evaluate the utility of the Students' Monitor. Two groups of students are required. Both are evaluated after a teacher's lecture by means of a contents questionnaire. One of the groups will have a teacher assisted by the Students' Monitor. Significant deviations should be identified to show the effectiveness of this virtual device.

a) The effect of being monitored. The behavior of students can change when they know that they are monitored. This should be researched. V-LeaF allows both policies: silent and classical monitoring.

3) Evaluate the efectiveness of the Teacher Evaluator. In a similar way to the evaluation of the Student's Monitor, the efectiveness of the Teacher Evaluator module should be tested with two sets of users.

B. *Evaluations wars*

Let us image a classroom in which students evaluate the teaching quality (perceived quality) and teachers pay attention to students' gaze inattention. It could be the case that students with low gaze attention became stressed by the teacher, resulting in a negative feedback for both students and teachers. This kind of destructive effect between virtual devices could be an interesting matter for research.

V. Conclusions and Future Work

For many years, immersive environments have shown that teaching can be improved in different ways. For the last years, the fast development of personal computing has resulted in powerful computers with graphical features capable of providing users with rich 3D virtual worlds. Many of the lessons learned in immersive environments can be applied to these new low-cost environments.

Our team has built, on top of the OpenSim platform, a software infrastructure, named V-LeaF, initially oriented to high school students and teachers but with a wider application scope. Any social task involving avatars can benefit from this platform.

One of the results of the application of V-LeaF to real high schools was a list of "useful" teaching virtual devices, identified by both teachers and students. The most relevant virtual devices created are shown in this paper, as well as the experiments that can be carried out. As we have described in section IV, next steps will include several experiments with educators and students from high schools to obtain analytical measures of the results by using our new monitoring device.

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Enhancing Authoring, Modelling and Collaboration in E-learning environments: UNED research outline in the context of E-Madrid excellence network

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***Abstract*— In the last years, authoring based on e-learning standards has been consolidated as a core factor of industry and development of interoperable and effective virtual learning environments. However, there is a need for further research on abstraction to provide a more instructional view in the context of authoring tools in a variety of ways, in order to avoid being driven by Learning Technology (LT) specifications, facilitate instructional knowledge aggregation, and to provide an appropriate level of clarity and semantics in the design of collaborative activities. We propose a combination of techniques to provide this instructional abstraction in the context of the new European educational model, combining instructional layers and collaborative scripts in authoring tools, and semantic web techniques for extending e-learning material in order to harness the wealth of existing web content and semantically labeled repositories.**

Keywords: E-learning content modeling, Educational authoring, collaborative learning, e-learning standards, Semantic web

I. INTRODUCTION

The generation of educational content and design of collaborative activities has always been a big effort, especially because in many occasions the objective of the author or group of authors is to reuse existing resources and develop a complete course, including complex activities with content and user interactions. If the main goal of a learning object (LO) is to be used for teaching and learning, the second one in importance should be its reuse. To this end, extensive research has been carried out in the last years to standardize learning content components and collaborative interactions [14], to make them usable in interoperable and maintainable content repositories. To organize and help in the retrieval of the right LOs, metadata labels have been defined and standardized. But this has introduced an additional burden, namely that of annotating LOs appropriately following these metadata.

In this context, gathering educational content is a matter of two factors (a) reusability, which implies to have the resource at the appropriate level of granularity, and (b) availability, which tackles the idea of actually finding the most appropriate resource using a variety of techniques. The fact is that authoring tools usually do not implement features for these two factors and generally also lack of the appropriate abstraction level to provide an efficient way to search and retrieve content and on the other hand, a suitable way to describe learning courses at an instructional level of abstraction.

To overcome these problems in authoring of educational material we propose a combination of techniques to provide instructional abstraction by means of instructional layers, collaborative scripts in authoring tools and semantic web techniques for extending e-learning material in order to harness the wealth of existing web content and semantically labeled repositories.

II. INSTRUCTIONAL LAYERS, KNOWLEDGE MODELLING AND COLLABORATION

From the instructional point of view, the notion of Learning Object has been extrapolated from a variety of computational paradigms like *reusable component* as a software engineering concept, providing structured reusable elements labeled with metadata, and also from knowledge engineering, allowing content organization using knowledge-based structures like ontologies or semantic web development. On the other hand, from the cognitive sciences perspective, the adoption during the 50s and 60s of some instructional theories based on cognition have obtained useful abstractions to specify appropriate methods and situations in which those are to be applied during learning process [7].

In this scenario, very rich tools are available to tackle with the problem of providing flexibility in the creation of courses based in the aggregation of LOs [1][2]. However, this authoring tools have not evolved in a parallel way to be instructional aware, and still focus strongly on LT specifications and implement a LT specifications' syntax driven approach to implement the process of authoring [15]. The authoring of learning content has similarities with the COTS software building model, as it combines creation from scratch and reuse and modification of existing content, freely available on the network or stored in repositories. In this case, the reusing process needs some meaningful way to search and retrieve the appropriate content shaped as learning objects (LOs). Current research agrees that approaches based on a plain classification of LOs by means of a metadata labels lack a meaningful way to search, retrieve and reuse LOs from an instructional perspective. The reason for this drawback is based on the fact that (1) from an instructional perspective, retrieval of a collection of LOs by matching metadata attributes does not replicate the way a teacher operates when creating its own material, and (2) from the authoring perspective, the construction of metadata instances is very costly and not as precise and consistent as desirable.

A. Using knowledge modeling to improve authoring, collaboration and virtual learning communities

It has been mentioned that people is actually a killer application of the Internet, and it is with people and some organization that impressive results are achieved at low cost (for instance, del.icio.us, Wikipedia, Twitter, or the syndication of blogs) [31]. In this sense creating educational content can also be done by users providing the appropriate environment. Several repository efforts have been launched but they have not yet taken off.

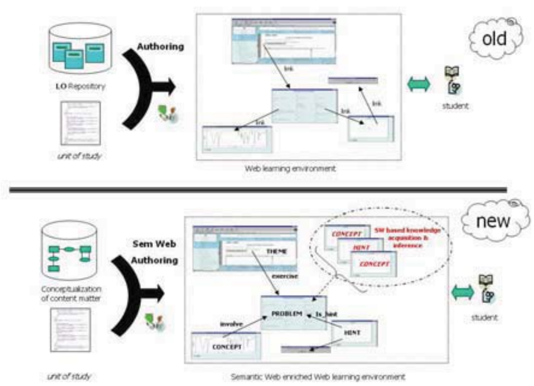

Figure 1: Semantic annotation of educational content

Sometimes the problem is one of granularity: the presentation of the learning resources is too broad as to ease the reuse of specific content. But if the granularity is too small, it is more difficult to have a good overview. Concerning this point, we agree with the approach proposed by [19] of using Topic Maps. Actually, we have already explored that from the teachers' point of view, authoring of educational content is easier to create if it is previously instructionally structured based on a pedagogical ontology (See Figure 1). This way teachers can refer to LOs like i.e. '*I would show here examples to illustrate this concept*' or '*exercise this concept solving this problem*' or '*give me a hint*'. We can be even more precise by saying *'insert here some easy examples to illustrate this concept'* and so on [2].

In the current way of retrieving LOs, we look for terms that match the metadata attributes, but without asking for a precise instructional relationship. So, the retrieved elements will have to be filtered one by one. We proposed to embed a semantic query language in LT specifications and the creation of a semantic layer based on the conceptualization of a subject domain. We think educational content authoring is a 2-step process. Firstly, there is a need to create an instructional view of the learning content at a low level of granularity. In this sense, some works suggest the use of semantic layers to organize information in the repositories [19]. Our approach also proposes using a semantic layer, except that we use RDF/OWL [24] [23]. There is a very strong relationship between RDF and Topic Maps. Simply stated, one could say that RDF provides a simpler and less specific model, based on more fundamental concepts. It is thus more flexible. Moreover, the possibility of reasoning with tools such as CWM or Pychinko, provides us with a tremendous power, allowing the inference of new information from existing metadata by the use of rules [18].

Some ideas are possible in this respect. As we have already evaluated authoring can be combined with topic maps as a way to link LT-based specifications to a cognitive-based framework [8], where LOs no longer remain as isolated components and act as a part of instructional ontologies. One way for improving LT-based specifications could be using embedded languages for allowing the creation of semantic instructional queries and referring instructional content at a higher level of abstraction [15] [6]. This authoring model would allow also the creation of dynamic links in the educational content, creating on the fly content in the case the reference had been updated, obtained by a direct reference or by means of inference of semantically labeled resources using reasoning link CWM and that is partially developed in [18] and [31]. The objective in this sense is not so much the development of new content specifications based on learning technologies or e-learning standards, but to use consolidated specifications such as IMS stack to integrate on them some mechanisms that allow the use of the described techniques with the objective to validate them in a real context of virtual campus. Going beyond reasoning, semantic web techniques have also a huge potential for enhancing eLearning search and retrieval, such as selecting, recommending, repurposing and reusing learning resources or tailoring learning activities to a given social or working context. Ontologies lie in the core of these techniques as they are able to provide a formal and shared conceptualization for every aspect within a learning set-up and scenario and to infer new and unforeseen facts implied by the available knowledge. Hence, we propose using ontologies as the foundation for the aforementioned semantic layer. Besides, using ontologies could help characterizing LOs in terms of semantic entities instead of the traditional syntactic approach. It has been signaled that retrieving LOs from a repository by searching field contents fails to catch the user's intentions, which tends to make its results either inaccurate or inadequate for the user [25]. Furthermore, as metadata standards impose a number of constraints on the possible values, learners and educational authors are supposed to know the right searching terms for a given query beforehand in order to get a good precision and recall. Ontologies allow turning syntactic metadata into semantic annotations as well as enabling searching for resources in a way far richer and closer to the users' needs than a mere keyword search. In this sense, instructional uses of the LOs are a distinctive trait, which could be used to drive the searching process, thus allowing a new kind of meaningful, *usage-directed* semantic query.

A number of techniques are going to be used to achieve this goal:

- Ontological Engineering, including locating candidate ontologies to reuse, aligning and merging them and building the lacking parts by using ontology design patterns such as those described by [26] for obtaining or building set of ontologies gathering all the necessary knowledge and representing every relevant instructional entities and relationships, making it explicit and easier to (re)use as well as binding the instructional ontologies to existing educational standards (such as SCORM, LOM or IMS-LD) for enabling the interpretation of existing metadata to bootstrap the semantic annotation process.
- Inference techniques, based on Description Logics [23] [28] and rule-based engines[30].
- Semantic annotation based on the representation and efficient retrieval of terms related to the aforementioned ontologies [29] [24]. As a result, it will be facilitated the reuse and repurposing of available Learning Objects (or their meaningful components) both in an Learning Object Repository and on the web.
- Clustering techniques for discovering new knowledge gathered from the web, such as FCA [27].

All these techniques are to be applied bearing in mind the pedagogical objective of designing a recommendation mechanism based on semantic search and able to cope with the actual needs of instructional designers and learners that would create a new kind of LO, which could be named *recommendation* LOs. Such a LO, would consist of contents collected from the web as the result of an *usage-directed* query as described before.

B. *Modeling collaboration*

The field of e-learning, collaborative learning is a pedagogical paradigm that is getting a growing acceptance. It is articulated by arranging a set of students into a number of small groups to carry out several learning activities together. Within these settings, learning objects, rather than being provided by teachers and instructional designers, arise as a consequence of the joint work of the groups supported by collaborative tools. These new kinds of objects have been coined as ELOs (Emergent Learning Objects).

The paradigmatic shift consists in moving from the teacher-centered perspective, where the instructor delivers the appropriate contents to the students, to the learner-centered one, where students take a more active role while teachers mediate and moderate the learning process. Articulating its instructional workflow requires storing and later retrieving ELOs. These objects have to be characterized with respect to a new dimension, that of the collaborative context whence the ELOs arise. And furthermore, the collaborative context where ELOs emerge can help automating their characterization in terms of context-dependent metadata. It is quite important to determine the elements to take into account to populate the context for facing these requirements. Examples of such elements would be the collaborative activity being developed, the group or the involved tools.

Socio-collaborative context elements are fed from the collaboration-oriented virtual learning environments (VLE), and particularly, from the use students make of them and their integrated tools. Hence, VLE must be built taking into account four main requirements:

- Defining the social structure for the underlying virtual learning community (VLC) where the learning scenarios are to be unfolded and particularly, the set of groups and types of users required for this development.
- Designing the collaborative work that learners will be involved in, including defining activities according to a pedagogical method, describing their sequencing along an instructional workflow, defining the roles suiting an appropriate division of labor, etc.
- Supporting the collaborative interaction by integrating an open set of external mediating tools within a VLE. The integration mechanism must provide a sufficient interoperability level for the users to perceive a smooth sense of continuity in their learning experiences. ELOs are, in this sense, a main resource as a vehicle to provide functional connection between tools an so achieving the desired interoperability level.
- Catching all the dynamical aspects inherently bound to the collaborative learning scenarios specification, such as, creating informal learning groups within the experiences lifespan, supporting activity monitoring and control or assisting the evaluation and grading tasks.

To face these requirements, we have developed the PELICAN e-learning platform [20] [21] [22]. Different users can perceive this tool from several complementary perspectives:

- PELICAN as a design tool. PELICAN is used by instructional designers as a design tool to define collaborative learning scenarios. The platform provides a simple and flexible modeling language to allow the definition of all the aspects related with collaborative experiences (social arrangements, collaborative work, monitoring rules, collaborative evaluation strategies, etc.) Notice that these specifications could be reified as LOs to foster their reusability along different pedagogical contexts and reduce the design efforts.

- PELICAN as a VLE environment. From the students' point of view, PELICAN is perceived as a collaboration-oriented VLE. Hence, it provides the required technological infrastructure to support the previously designed learning scenario development such as shared virtual workspaces, access to web references, interaction services and so on.
- PELICAN as an integration platform. PELICAN can also be considered an integration platform as it provides several mechanisms to incorporate external tools supplying interaction services to virtual workspaces at various integration levels.

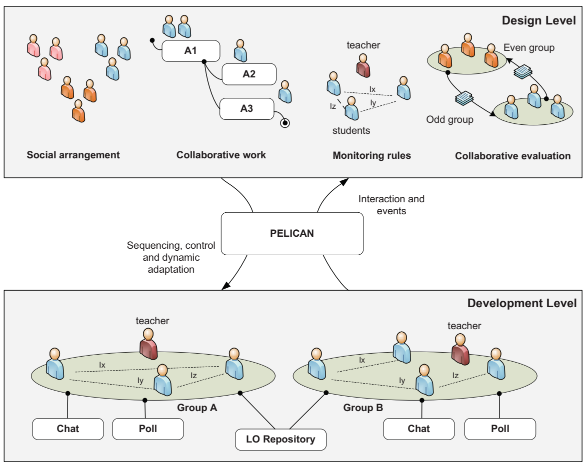

Figure 2: Two working levels within PELICAN

According to these three perspectives the instructional workflow in PELICAN is stated at two working levels. As it can be seen in figure 2, within the design level instructional designers specify in a formal and computational way all the aspects related with the learning scenario being undertaken. At development level, teachers deploy the design of a learning scenario along one or several workspaces bound to different socio-collaborative contexts. Between these two layers PELICAN is located as an orchestration mechanism to synchronize instructional workflows within each workspace with the prescriptions expressed in the scenario specification at design level.

III. INSTITUTIONAL POLICIES: E-LEARNING STANDARDS AND EDUCATIONAL METHODOLOGIES IN THE CONTEXT OF EUROPEAN EDUCATIONAL SPACE

In the current arena of educational standards, the development of ad-hoc standards leads to a large extent forced the re-use of existing ones. Given the new production framework being proposed here, where educational institutions need to adapt the content life cycle towards a sustainable model, they have to combine their own research and development in the area of educational standards. Given this approach it would be possible to integrate lecturers into the authoring of standardized content via a strategy of institutional production using tools that implement instructional design in the abstract sense reflected in their VLEs, and thereby avoiding the use of syntax driven tools. The UNED has since 2006 being generating open content, specifically Open Educational Resources (or OERs), marked up using various educational standards. Specifically, given the accessibility needs of an important part of our students, these resources needed to include meta data not only on the type of content but also its structure and the way in which it can be adapted and presented to students with special needs.

A. *Deploying e-learning standards policies*

Distance learning in virtual environments allows intensive use of new technologies, especially in the field of creating and managing multimedia content. The use of multimedia resources, either as asynchronous or synchronous learning tool in virtual environments can improve content learning with a high visual and interactive effect. But multimedia source material is diverse, ranging from video lectures to radio broadcasting, videoconferencing and slide presentations developed in many different formats.

This availability of this highly heterogenous bunch of educational objects implies that a single standardized metadata schema does not conform, as a rule, the definition of an educational repository metadata architecture, as in the case of an organization like UNED. In this context, the development of an application profile specifically designed for a LO repository with large multimedia component is highly important, being necessary to correctly define a set of metadata associated with the nature of the object which will structure and identify all elements and relations between them. In this sense and, overall, the use of standards-based content description XML allows to describe completely and extending all the elements that are part of a course.

Using XML as a standard basic language for describing content is widespread used in e-learning standards based on LOM, DublinCore and others, as well as schemas for description of multimedia (MPEG-7 is an example) or the packaging of objects (eg, SCORM). Therefore, it is perfectly feasible to full integrate the profile as a standard inside an environment that fully uses the other, providing they have a common language and a consistent set of metadata.

This new application profile will result from the integration of different standardized metadata schemas (generic, such as Dublin Core, educational like LOM, and multimedia such as MPEG-7) and represents the first step of a long process to ensure consistency and reuse of these contents in the future. Taking LOM as a starting point it may be a good choice, or at least an appropriate option but will implya greater effort (as far as labeling is concerned) in relation to other alternatives such as DublinCore. Moreover, at present, there are many more application profiles based on DublinCore than in LOM. This does not mean in any way, that the use of DublinCore is most appropriate. The reason is based mainly on one side in the simplicity of the Dublin Core metadata (as opposed to a larger number in LOM). For another, the more "generalist" DublinCore pursued against a better "educational" search with

LOM. In any case, as shown in this document and the referenced literature, it would be more difficult making the transition from a profile based on Dublin Core to a profile based on LOM than viceversa.

The subset of LOM metadata related to technique or technology will be somehow redefine to accommodate the huge volume and type of learning objects along with a set of other standard schemes which will define more precisely the audio and visual properties of the objects. In the case, the metadata that are commonly used in the LOM standard will be integrated in the data flow described by the MPEG-7, so that the latter becomes a comprehensive description of the reusable learning objects [32].

B. Software and content accessibility conformity

ICT technologies led each student to fulfill their learning process at their time, place, pace and capacities, but if the methodology is non-accessible for people with disabilities it is completely useless. Attention to diversity must be paid continuously, as the learning process is a continuous mode.

A critical issue to improve drastically the quality of the educational process is the development of high quality on-line learning resources and educational software [33] and the accessibility level of these materials will make a difference. A precise control must be taken into account over the creation process, analyzing the existing standards for learning resources, their level of accessibility, developing new laws, directives, standards, specific guidelines and new authoring tools. The appearance of Open Source development tools for SCORM compatible materials has achieved a great goal [34].

Non-accessible web interfaces prevents and hinder right access to information and services for Internet users. Even W3C (World Wide Web Consortium) promotes since many years accessibility standards and guidelines for both content development and authoring tools, reality is highly disappointing. The problem of accessibility is not yet understood by developers and producers and also there is still a lack of development frameworks covering the whole software development life-cycle that include accessibility checkpoints.

Lecturers and learners should be provided with specific means so that they can interact with learning material regardless of disability, benefits of accessibility compliance are not only for people with disabilities, but also for elderly people, all users in general. Learning environments will be Web based in most situations [35], therefore Web materials displayed into LCMS must be available for all users. The materials will run with the same behavior in all environments, have a consistent user interface and be easily navigated so that the content can easily be accessed and understood. IMS GDALA (Guidelines for Developing Accessible Learning Applications) offers specific guidelines for design and development of e-Learning applications in all the lifecycle and W3C/WAI WCAG (Web Content Accessibility Guidelines) give general guidelines to achieve accessible content.

Lecturers create learning content using above standards. Courses will be delivered and display through an e-Learning platform - that is in fact a Web based application - therefore greater flexibility and automatic processes are desirable from the point of view of the creator, commonly the lecturer. Authoring tools are the main point in the stages in the creation of educational content. The most widely used technical development so far is based on the use of validation and verification tools for web content after development. This validation cycle model is close related to the methodology called software prototyping based on the creation of prototypes, i.e., incomplete versions of the software program being developed. A prototype typically simulates only a few aspects of the features of the eventual program, and may be completely different from the eventual implementation.

The chances of the result of the validation process vary depending on the project and the available resources, in most cases it is reduced to the validation of the use of standards and accessibility and omitting the rest of the characteristics involved. Some authors propose methodologies based with an expanded user-centered development. In this type of solutions, starting from a simple design and considering all users, accessibility requirements are considered at first, before the initial prototype is developed, along with the rest of software requirements. Therefore in this model, the prototype is evaluated in the most possible ways obtaining then the most complete error report.

In another category are those solutions based on the development of web content using authoring tools that include accessibility standards like (X)HTML and CSS. At first they represent a guarantee of compliance with W3C standards and other requirements of accessibility and usability. Often these authoring tools also include validation tools or links to them, being designed to operate in a similar way as the validation cycle model. Such tools (as the ones that comply with W3C ATAG guidelines) are one of the best alternatives. In practice, it is a limited solution, having trouble with dynamic web pages or parts that are not included in the set of standards. As in the previous case, there is an intermediate solution being used only for the development of specific content based on (X) HTML or CSS.

In a new category one could gather all those new technologies arising from technical innovation around the Web 2.0 [36]: developments that use sets of Web 2.0 standards, Rich Internet Applications (RIA), Semantic Web or Micro formats. Actually, the application of these techniques usually takes place as a whole in the project so that it is analyzed through a unique hybrid model that represent simplified solutions. The use of Web 2.0 elements benefits accessibility:

- they are standardized elements already,
- there is the possibility of reutilization of models with RIA Mashup components,
- many metadata information exists to provide Semantic Web functionality.

Regardless of the use of RIA technologies, other authors defend in any context the use of semantic information in addition to accessibility aiming the usage of standards (X)HTML, CSS, XML for data and SOAP and DOM for data exchange and interaction. This concept is at the heart of Web 2.0, and thus is implicit in the use of these technologies. Alongside, he believes that Semantic Web complies accessibility conformity of software components because of the metadata information also easier from RIA technologies because it has been taken into account almost since its inception. Finally, the semantic information is supplemented with the use of Microforms or metadata patterns that complement those elements likely to present accessibility problems.

Regarding the scope of this solution, it is beneficial because it provides innovative technologies for web development. RIA technologies certainly give greater power and functionality to the web, besides being really closed to accessibility conformity because of the use of web-based standards and reutilization of components. Still in the area, Mashup development ensures separation of structure and content, facilitating the publication of content with a minimum and accessible version from any application or Web service. On the other hand, the semantic information through metadata is a very valuable partner to enriched components, so that that they can be interpreted by assistive technology tools and accessibility APIs for platforms.

C. *The European Educational Area*

In a broader context, the new European Area [9] and its convergence in education designed a model closer to what today is conducted in North America and Japan. In such systems is given greater importance to the practice load during the conduct of a subject. By providing an orientation toward more experimental tasks, and a clear direction to the working world, students develop a range of skills than in degrees with less experimentation do not have. This is an excellent testbed to carry out institutional standardization policies.

The most visible set of changes involves the abovementioned adoption of a US-like unified cycle structure involving graduate-master-doctoral cycles, as well as the adoption of a single unit of measurement, the ECTS (European Credit Transfer Systems) credit (which refers to 25-30 student hours of total effort, rather than being measured in hours of face-to-face lessons as before). In many countries (such as Spain), this involves the re-design and thus the (re)accreditation of all the degrees, under the quality certification system required by the EHEA. This massive, simultaneous redesign of all degrees presents daunting challenges but also offers unprecedented opportunities. On the one hand, since all degrees must be simultaneously redesigned, synergies among them can be effectively exploited, thus encouraging the re-utilization oriented approaches discussed in this paper (LCMS, standards like LOM, Dublin Corem QTI, IMS, SCORM, etc.). On the other hand, shifting the unit of academic measurement to student hours (through the ECTS) facilitates the seamless combination of face-to-face, distance and blended learning in academic degrees.

The other, maybe even more significant but more subtle set of changes are those aimed at shifting the focus from instructor-centered “teaching” to student-centered “active learning”. It involves methodological changes such as continuous evaluation, de-emphasizing theoretical lectures to focus more on assignments and projects, higher practical focus, allowing students higher flexibility to design their own curricula. When combined with budget limitations, this methodological shift strongly supports the introduction of effective IT based approaches to alleviate the burden on the instructor’s resources. These should facilitate the educational equivalent of the current manufacturing trend towards “mass-customization”, thus allowing individually tailored learning paths with a level of resources similar to that required by standardized education. In addition, several countries are taking this opportunity to introduce far-reaching modifications in their educational systems, which further strengthen the case for the introduction of IT based educational innovation. For example, in Spain, until now, all “official” degrees were listed in a catalogue compiled by the Education ministry (universities could also grant their own degrees on whatever they wanted, but those did not have official recognition). This catalogue included the name and the degree curriculum (structure), up to certain level of detail. The new system, however, breaks away from that closed catalogue approach and just issues some very generic guidelines to which new degrees should conform. Within this framework, universities (both private and public) are free to propose whichever degree titles and supporting curricula they want. Once the proposal is cleared from a quality criteria point of view (general quality criteria, such as the faculty CVs, cohesiveness of the proposed degree curriculum and appropriateness of the supporting IT infrastructure) the new degree is inscribed in a national registry, and the university is free to offer it (subject, again, to periodic quality evaluations).

One last aspect worth highlighting regarding the EHEA is its emphasis on promoting mobility and the international dimension in education (through joint international degrees or through mobility in selected subjects of end term Thesis). Again, achieving this objective would be assisted by the adoption of standards-based, location independent IT-based educational solutions. These should support both distributed provision of learning services (e.g. in degrees offered by consortia of universities) and their consumption by distributed student groups, facilitating not just the interaction between students and instructors, but also the increasingly critical interaction among participants in distributed teams.

IV. BACKGROUND OF UNED RESEARCH GROUPS

Researchers in the UNED belong to LTCS[1] (LSI Dept.), G-Elios (DIEEC[2] Dept.) or ATLAS[6] (Modern Languages Dept.) groups. Some of their members also belong to the CINDETEC unit, a Vice-chancellorship that coordinates the university's e-learning infrastructure.

The LTCS Group is made up of researchers from the LSI Department at UNED and external collaborators that work developing projects which apply learning and collaborative technologies to the support of human activity in distance learning scenarios. The research is based upon:

- Knowledge-based Authoring
- Collaborative modeling in educational contexts
- E-learning standards
- Software and Content Accessibility conformity

The group's research lines can be situated within the area of educational technologies, specifically learning, both individual and collaborative. The first relates to different aspects of instructional knowledge representation and its normalization. The second is centered in the problems associated with collaborative learning and the mechanisms that sustain and define the activities that configure it. The third goes from the description of the collaborative workspaces or mediational tools that facilitate the communication between distinct agents in the process, to the analysis of the process based upon records of the activities undertaken. The latter reinforces accessibility issues while delivering eLearning services.

The group has participated in the following project in the last years: ENLACE[1] 2005-2007 / COLDEX[2] IST 2001-32327 (IST program)/ EA2C2 [3] (TIC 2001 -00007) and CELEBRATE [4] (2002-2004) IST-35188 / e-XCELLENCE 2004-3536/001-001 EDU-ELEARN and eXcellence+ action 2007 – 1999/001-001 TRA-MULPRO[5] and EduTubePlus 2007 EDU 427003[6].

As well as working in different research projects, the group participates in other activities that promote investigation and its diffusion, taking part in summer courses, doctoral courses, and specialised seminars and congresses at both national and international levels.

The G-Elios group belongs to the Department of Electrical Engineering, Electronics and Control (DIEEC[7]) of the School of Industrial Engineering at the UNED has a major focus on research in the Advanced Educational Technologies Applied to Engineering, with special emphasis on e-learning, due to the model of teaching in UNED (which is distance education). This characteristic makes that communication between teachers and students is especially in a virtual way, ie through some form of electronic means, primarily through e-learning platforms. This means that individual departments and research groups from the University are working on this route in order to improve the attention offered to its more than 200,000 students.

1 http://:enlace.uned.es
2 http://www.coldex.info
3 http://sensei.lsi.uned.es/ea2c2
4 http://celebrate.eun.org/eun.org2/eun/en/index_celebrate.cfm
5 http://www.eadtu.nl/e-xcellenceqs/
6 http://www.edutubeplus.info
7 http://ww.ieec.uned.es

In this sense, the DIEEC, has over 10 years working in the area of e-learning, with 14 national and international projects. Worth quoting some of the most recent international projects such as “PED -CARE (Pedagogical Distributed Group Care)”, “Elearning Thematic Network”, “Internet-based Performance Support System with Educational Elements”, “IPLECS – Internet-based Performance-centered Learning Environment for Curricula Support”, “mPSS – móbile Performance Support for Vocational Education and Training”, “SOLITE SOFTWARE LIBRE EN TELEFORMACIÓN”. And in the national scope, "s-Labs –Integración de Servicios Abiertos para Laboratorios Remotos y Virtuales Distribuidos”, “MOSAICLEARNING: Aprendizaje Electrónico Móvil, de Código Abierto, basado en Estándares, Seguro, Contextual, Personalizado y Colaborativo” o“Comunidades Virtuales de Alumnos” as an example. The G-elios research group (Grupo de Investigación en Ingeniería Eléctrica y Tecnologías Avanzadas en Educación, Electrónica, Control, Computadores, Energías Renovables, Sostenibilidad, Movilidad y Comunicaciones) meets 22 researchers (the mayority of them with PhD degree) within the department.

Finally the ATLAS[8] group has been working in the area of intelligent language learning systems for several years and has been involved in a series of funded research projects: The Virtual Verb Trainer (VVT), The Virtual Authoring Tool (VAT), I-Peter I, I-Peter II, COPPER and I-AGENT, the latest and currently ongoing project with a Ministry of Education grant, number: FFI2008-06030.

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Session 06A Area 1: Uses of Technology in the Classroom - Engineering Applications

A technological platform for teaching control engineering

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Motivating Younger Students by Using Engineering Graduation Projects to Facilitate their Work

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FPGA/Embedded system Training Kit Targeted to graduate Courses towards Industry level short training

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Carrasco, Juan M.; Domínguez, Eugenio; Franquelo, Leopoldo G.; León, José I.; Portillo, Ramón; Sánchez, Juan A.; Vázquez, Sergio
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A technological platform for the teaching of control engineering

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***Abstract*— This paper presents a technology platform as a resource for the teaching of control engineering. The platform in question combines the educational potential of software of design and simulation of control systems - MATLAB ® - and the connection between this software and a pilot distillation column. The research hypothesis is that the use of technology platforms such as this helps to develop aspects not only stimulated with simulation. Therefore, an experiment based on the constructivist and social-interactionist theory has been designed to detect student development and to capture their impressions of the platform. The results are presented as graphs and impression reports of the teacher.**

Keywords-technological platform, control systems, constructivist theory.

I. Introduction

Emphasis on the teaching of techniques instead of concepts results in a fast forgetfulness by students. The teaching of theory detached from practical aspects does not properly prepare the student for his professional life [12].

Nowadays, the teaching of engineering and the methods used by teachers do not significantly contribute to the development of skills and competences needed by professionals, especially in a control engineering and automation course.

The theories selected for didactical and pedagogical conception of this platform have as their main argument the attempt to approach teaching of engineering – typically instructionist – to the most adequate paradigm for building knowledge and inherent competences to this professional, opposed to the positivistic and behaviorist theories that prevail in this segment of higher education. Such platform, which has a system and control project and simulation software and integration between the simulation software and a real scaled system, provides students with a favorable environment to the development of competences and skills required to their jobs.

According to [11] recommendations by the Accreditation Board for Engineering and Technology (ABET), an American institution that aims at establishing specific quality criteria for each major, undergraduate courses should encourage the ability to apply knowledge of mathematics, science and engineering; design and conduct experiments; analyze and interpret data; design a system, component or process to meet desired needs; function on multi-disciplinary teams; identify, formulate and solve engineering problems; understanding of professional and ethical responsibility; communicate effectively (written and orally); understand the impact of engineering solutions in a global and societal context; engage in life-long learning; use the techniques, skills and modern engineering tools necessary for engineering practice.

Through an appropriate computational support, this professional in formation has access to common problem situations in their professional environment, as long as a didactical and pedagogical strategy by the teacher favoring the student's production/authorship and development is used in association. To do so, certain aspects must be outlined, such as the evaluation process.

In engineering courses, teachers, who are excellent conveyors of knowledge – as if knowledge could be conveyed and not built – usually regard evaluation as a confrontation process between the teacher's questions and the student's answers, searching for an approximation measure between both to generate a likely grade or concept that represents the entire individual learning throughout the term.

Following the knowledge building process implies favoring student's development, guiding them in tasks, offering new references or explanations, suggesting investigations, providing enlightening experiences to foster knowledge expansion [6].

Within the context of a formation based on paradigms that originate from constructivism, critical-dialogical and social-interactionist pedagogies, educational evaluation is not something detached from the large procedural set that configures formal school and college education. It is intrinsic to educational practice, teaching and learning [1].

However, a learning evaluation process should be continuous and present throughout the entire teaching-learning process, a limited evaluation such as a test is not able to represent all the knowledge built in the student's cognitive structures.

This study is structured as follows: the second section presents a brief state of the art of using similar technological platforms; the proposed technological platform is presented in the third section, stressing its main constituent components. The fourth section presents the proposal of a didactical-pedagogical experiment, and the fifth section brings the results of the case study. Final considerations are discussed in the sixth section.

II. A BRIEF STATE OF THE ART

The state of the art that congregates several studies related to the proposed platform can be quite briefly approached in the following paragraphs. It is important to stress that, in spite of the similarity of the proposed platform with varied remote laboratories mentioned in the studies below, this work aims at using the technological resource as a facilitator for a didactical-pedagogical experiment to investigate the importance of this platform for the teaching of control engineering and automation.

Aktan et al. [2] use the paradigm of distance learning, in which students, teachers and equipment are geographically separated, to develop a remote access real-time laboratory to teach control engineering. The entire apparatus enables students to develop and depurate distance programs and then carry out online experiments to control a robotic manipulator.

Liou et al. [7] used the Labview software to control electrical systems, such as RLC circuits and electric engines. Users use the Internet to access Labview parameters and are able to interact with the systems simulated by it.

Schmid and Ali [10] developed an Internet-based system to teach control engineering. This system enables a more comprehensive visualization and simulation of dynamic systems due to use of a standard web browser. Virtual Reality Modelling Language (VRML) is used to animate dynamic systems. In addition to these resources, the virtual course is composed of tutorials, exercises and virtual experiments.

Clume and Gomes [4] presented a system for remote control of real-time processes using the Internet, following a client-server architecture. A project interface and fuzzy controller tuning is made available for the user. The remotely accessed equipment is a pendulum. Tests were performed at Universidade Federal de Juiz de Fora (UFJF) and at Universidade Federal de Santa Catarina (UFSC) to validate the capacity of system remote access.

Zeilmann [13] presented a proposal of control, supervision and monitoring of industrial processes by the Internet. He presented the study under the perspective of three contexts: industrial plant, server and client. Through integration of web technologies and fieldbus networks, it provides remote access for users to the devices communicating via Foundation Fieldbus protocol. It is an advancement in relation to other remote laboratories due to the proximity between the pilot plant and those found in the industry.

Casini et al. [3] developed a laboratory for the remote teaching of process control techniques. Control modules available at the laboratory are position control, speed control, both of a DC engine, tank level, and helicopter simulator.

It focuses on competition between users and their control algorithms, creating a ranking for those who develop algorithms with better performance.

Dormido et al. [5] presented an online laboratory for experiments in a non-linear, multivariable system, three attached tanks, enabling students to learn in practice essential aspects of process control. Through the integration of EJS (Easy Java Simulations) and eMersion – collaborative tool for online experiments – people involved can have greater flexibility to perform experiments.

Based on this scenario, it is possible to observe a main focus on verification of tool quality only quantitatively and in the process of building such technological platforms. This study aims at observing the student's evolution during use of the tool, which basically takes an entire term, using two verification tools: a questionnaire for students and the records of a teacher's impressions.

III. THE PROPOSED TECHNOLOGICAL PLATFORM

Development of a technological platform for the teaching of control engineering and automation must pass through use of existing and available computational and technological resources at the laboratory of industrial automation of Instituto Federal Fluminense. These resources, commonly explored separately, now start to integrate an environment of project, simulation, implementation and tests for advanced control strategies.

Differently from many laboratories with remote access available in teaching institutions around the world, this laboratory aims to serve as foundation for studies by students enrolled in a regular and in-person course, making clear that the intention, at least not initial, of this study is not to investigate the advantages of these laboratories for distance learning.

The platform has three basic constituent elements:

- Real system, represented in the form of a pilot distillation column.
- MATLAB/SIMULINK®, control system project and simulation software.
- Integration of the above software with the real system through a mediation and acquisition system of industrial data – Foundation Fieldbus (SYSCON®) and the OPC servers that integrate Smar® SYSTEM302 package.

The choice for proprietary software is due to the fact that there is no equivalent software for function inherent to application, stressing that all software used is properly licensed. Figure 1 presents the constituent elements of the platform in the form of a diagram.

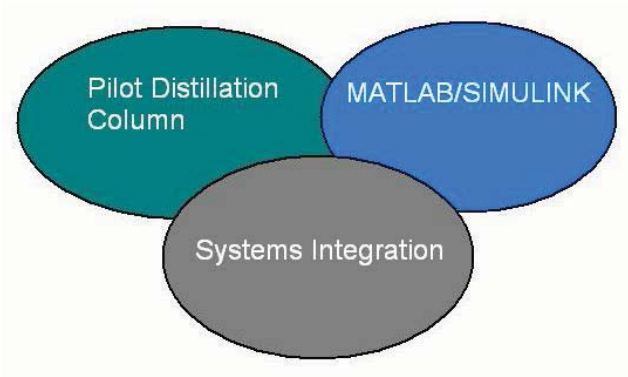

Figure 1. Components of the technological platform.

A. The Distillation Column

In many laboratories of the automation course of Instituto Federal Fluminense, there are prototypes of industrial plants and processes. Through systems of data measurement and acquisition similar to those used in industrial environments, these prototypes allow students to interact with the equipment and learn techniques of process control identification, which are used by control and automation engineers. Among existing laboratories, the pilot distillation column is closest to an industrial process in terms of instrumentation system and productive capacity. A picture of the distillation column can be seen in Figure 2.

Figure 2. Pilot distillation column.

B. Integration of Communication Software

This column has a supervision and control system quite close to the reality found in transformation industries, which base their processes in distillation, such as sugar mills and oil refineries.

Integration between SYSCON® and its installed OPC servers enables access to parameters of the instruments connected to the plant, which allows measurement of variables and acting in final control elements, such as flow control valves. Such availability of data will be used by MATLAB® for the last integration level, enabling control of the distillation column.

C. Project and Simulation Software

MATLAB® has great acceptance by engineers because it has toolboxes for many areas of scientific knowledge, especially engineering courses. In terms of control engineering, it has a graphic environment that works with the concept of block diagram and signal flow for the project and simulation of control systems known as SIMULINK®. After version 7, MATLAB® gained a specific toolbox for OPC communication, which is the most widely used dynamic transference protocol in the industry. This allowed the integration between a software program used at the university and industrial equipment, such as distillation column instruments.

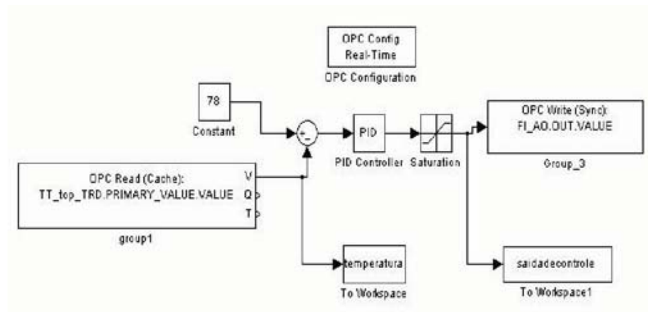

Figure 3. Control system with OPC communication.

Figure 3 shows a SIMULINK® screen with an implemented control system accessing instrument parameters from OPC communication blocks. Projected and simulated control systems by students can then be tested in the real system.

IV. EXPERIMENT CHARACTERIZATION

The didactical-pedagogical experiment was performed at Instituto Federal Fluminense and used as empirical field 8th-period students of the Control Engineering and Automation Superior Course, more specifically students enrolled in the advanced control course.

Certain aspects should be observed throughout the term so that, by the end of the course, it is possible to collect data and analyze results under the light of involved theories.

Taking such aspects into consideration, constituent steps are presented in the characterization of the didactical-pedagogical experiment.

Among these steps, the following stand out:

- Laboratory physical structure. Students use desktop computers with 2.4 GHz Core 2 Duo, 2MB cache, 2GB RAM, 120GB hard disk SATA, 19” Widescreen TFT LCD monitor in conformance with ABNT norms, ABNT2 keyboard. These PCs are connected to a Hub along with the Device Fieldbus Interface

(DFI), allowing access to the plant by all computers. License for MATLAB® version R2006a for up to 20 network machines.

- Verification of impressions relative to students' progress in the form of daily records made by the teacher. Excerpts of these records are shown in section 5.
- Record of students' impressions in relation to the platform. A modified version of the SERVQUAL tool – applied in verification of service quality – was used; further information will be presented in section 5.

This experiment proposes that during classes the teacher should provide idealization and problems for the student and play the role of a possible partner in the teaching-learning process either as a student helper or as an encourager of new investigations.

The steps of the suggested methodology to define and execute the experiment are based on the premise that it is not correct to see teaching-learning processes as a paralyzed process starting at a given point and ending at another with an evaluation of concepts. It should be regarded as a continuous process fostering daily progress and requiring periods of reflection between sequence processes of assimilation and accommodation and resulting in the much outlined reflexive abstraction [9] originating not only from the individual's actions, but also from action coordination.

Within such reality the proposed technological platform is inserted as an environment in which students are able to design, simulate and implement advanced control systems and test their performance on the pilot distillation column.

V. RESULTS

Results were divided into two parts; one concerns the reports of teacher's impressions in the classroom, and the other is relative to verification of an existing gap between students' expectation and perception when using the proposed computational platform.

Parasuraman et al. [8] presented the methodology used to create the SERVQUAL scale. It is an interactive process of quality assessment of five companies in the segment of services in the 1980's in the USA and subsequent verification of internal consistency of the questionnaires using Cronbach's alpha coefficient1. The authors reduced 150 original items to a questionnaire with only 22 items, which can also be reduced. This study only used ten items to be included in the questionnaire applied to students.

Choice for the SERVQUAL scale in this study was motivated by the facility to quantify subjective values and impressions of clients (students), and its important capacity to demonstrate the gap between expectation and perception by making verified aspects a little more tanglible.

Students evaluated each of the ten items in relation to expectation and perception. To do so, they had to sort the items into one position in the numeric scale composed of seven positions known as Likert scale2 because of its level of agreement with the presented statement. According to the excerpt taken from the questionnaire:

The technological platform helped performing the tasks.

1	2	3	4	5	6	7

Other examples of statements include the following: The technological platform is essential to perform the tasks; The platform was relevant to consolidate the concepts learned in the classroom; The technological platform helps us develop competences required to our professional formation. Ten statements were used. Based on the collected data by the questionnaire, it was possible to graphically establish the difference between expectation and perception in terms of response frequency, resulting in the chart shown in Figure 4.

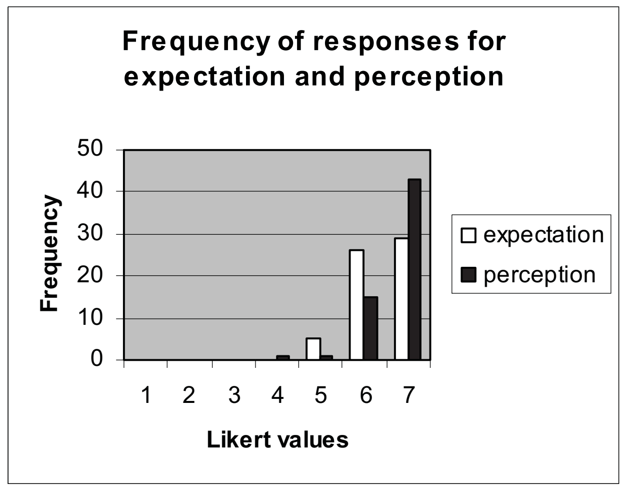

Figure 4. Response frequency chart for expectation and perception.

The chart in Figure 4 shows a quite high frequency for number 7 in terms of perception. It can be concluded that for most questionnaire items the students strongly agree with the proposed statement. The high frequency for numbers 6 and 7 in terms of expectation suggests that students had a good expectation toward the tool, which is positively confirmed in perception.

Students' follow-up throughout the term was performed on a daily basis by the teacher of advanced control. Only a summary of his impressions will be included in this paper, focusing on the most relevant impressions. The group is composed of eight students in the eighth period of Control Engineering and Automation. All the excerpts below refer to the teacher's statements.

> *In general, students had an excellent performance in this course. Such performance was seen by the*

[1] Cronbach's alpha is a coefficient used to measure the internal consistency of questionnaires.

[2] Likert scale is a five- to seven-point scale used to quantify subjective aspects.

> *end of the term, but knowledge was built at each interaction in class.*

Based on the teacher's comments, it is possible to note that students' progress during the term was evident, reflecting in performance results by the end of the term.

> *First students had expository classes of theoretical background about the main techniques of advanced control.*
>
> *At a given point, students were explained about use of the technological platform proposed for development and application of advanced control systems.*

Theoretical background was necessary to make students more able to achieve the objectives proposed in subsequent stages.

> *From then on, students were encouraged to work on projects and solve specific control problems using the platform. In many classes students had initiative and helped each other, showing ability for team work.*

By working with a new class model that favored participation and production, and encouraged to work on projects, there was an adequate environment for the development of highly valued competences, such as team work.

> *An assignment by the end of the term in which students had to design, implement and test an advanced control system using the proposed platform, showed they were already able to manipulate the tool. By the end of the term, students presented their projects and control systems, which were working according to specifications.*

It is possible to observe that they developed the main competence required to a control and automation engineer, that is, development and application of a control strategy for industrial processes.

VI. FINAL CONSIDERATIONS

The proposed environment aims at providing students with a favorable environment for the development of competences and skills required to a control and automation engineer, such as those presented in [11]. It was able to achieve the objective based on analysis of results.

The didactical-pedagogical conception of the experiment and analysis of results were developed to approximate constructivist theories, especially in aspects regarding proposal framework and tools used to obtain the results. Results achieved by application of tools were considered satisfactory for a pilot study. Such statement can be confirmed by presentation of results as a chart, showing acceptance of the platform by students, and also by the teacher's reports.

Further studies include application in other advanced control groups and development/use of new tools to follow the students' progress throughout the term, such as a daily report.

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Motivating Younger Students by Using Engineering Graduation Projects to Facilitate their Work

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Abstract—**This paper addresses a way to motivate freshmen students benefiting from the work of term students in graduation projects. The application of concepts from digital electronics and analog telecommunications systems can reinforce cooperation of students at different levels on a positive way and strength skills. This can also be used as demonstrative experiences to attract prospective students to electrical engineering courses. The experience of a cooperative work with graduation projects is presented and how it can facilitate younger students work and thus contribute for their motivation and skills. The graduation projects used are briefly presented and some results are shown and discussed.**

Keywords- Antenna measurements; computer aided instruction; cooperative work; graduation projects; electrical enginnering education

I. Introduction

Younger engineering students often face some difficulties with working methodologies, namely on how to take the maximum from individual and team work within the time slot available to accomplish the tasks. This is more noticeable at laboratory classes when a plan of sequential actions needs to be designed, discussed and performed within the group. Besides social and personal relationship factors – students often do not know each other very deeply at early stages – this is also due to a natural lack on basic technical background, skills and confidence, regarding their freshmen status. Although collaborative work and project groups are good learning methodologies [1], usually there is a diverse function within the team. Some students tend to assume a passive attitude while others, probably facing the same difficulties, try harder and focus on the main objectives. However, without a proper guidance and clear focus, both tend to become unmotivated, either by the apparent increase on workload due to the sense of missing results, or by the non-perception of what is really important, which is typical at early stages, as a consequence of a lack on non critical analysis and non critical thinking.

To keep or improve motivation, the idea of very difficult piece of work to accomplish or repetitive and useless tasks should be avoided, especially in cases that require a large amount of measures as is the case in antenna measurements. Rather, the adoption of a systematic approach and a focus on the meaning and importance of each step are of great importance. Some key factors that contribute to student's motivation are: a clear idea on the applicability of the concepts and a focus on "how and why it happens" or "how it works". Simple examples are computer internal architecture, the use of software to control the hardware, namely on using the computer peripherals (e.g. signal generation). Another key factor to increase motivation is the knowledge and the applicability of some graduation projects made by senior colleagues. Regardless its complexity, it may give to younger students the sense that they are also capable of doing the same or even better and in that way increase self-esteem.

The main objective of this paper is to describe a collaborative work experience with engineering graduation projects and how it is useful for freshmen students. These can serve as aiding tools on facilitating their work at laboratory classes, and enrich their skills on using a multidisciplinary approach. The paper is organized as follows: section II presents the motivations of this work, the graduation projects are described in section III, the collaborative experience in section IV and in section V we present a summary with the main contributions.

II. Motivation

The motivation for this collaborative work started in two main branches: one in the field of telecommunications and the other one in digital electronics. Two years ago (approximately) the authors decided to take advantage from the work of senior students on graduation projects to facilitate the performance of freshmen. Thinking on its use for didactic purposes on laboratories it was also decided to introduce some new features and increase their motivation with specific applications. Both were first proposed carried and supervised separately by the authors and at a later phase improved and connected in order to enrich multidisciplinary application of concepts.

A. Antenna Measurements

The Telecommunications Laboratory (Lab-T) at the Superior School of Technology of the Polytechnic Institute of Castelo Branco (EST-IPCB) supports the Telecommunications courses of the bachelor degree (3-year) on Electrical and Telecommunications Engineering. The Lab-T is equipped with several didactic kits and test equipment and supports, among others, the practical and laboratory classes of Electromagnetic Waves, Propagation and Antennas. The later is a second year, second semester course, studying subjects related to antennas

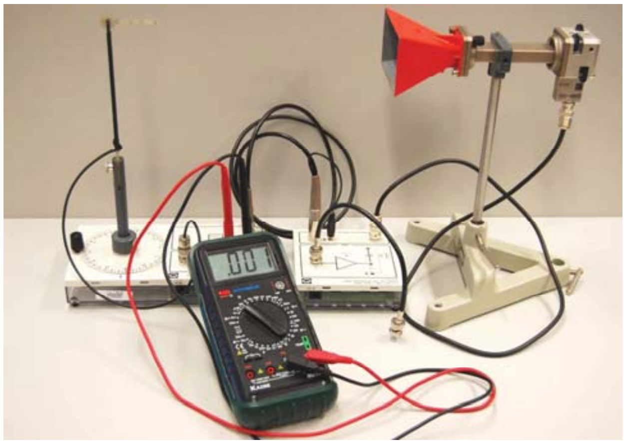


Fig.1. View of the main components of the MTS 7.6.5 antenna measurements station: TX antenna (right) supply and amplifier (middle) and RX antenna (left) with a Yagi structure.

in several different types and configurations [2]. One of the most common experiments carried at the Antennas course is the evaluation of the radiation pattern of linear antennas. For that purpose students use a Leybold–Didactic MTS 7.6.5 kit (the older version) shown in Fig. 1. The complete measurement station consists of emitting and reception terminals and a set of absorbing mats (not shown in figure). The emitting terminal comprises a horn antenna fed by a Gunn oscillator, which operates at 9.4 GHz, whose power supply is modulated, that is to say that the emitting electromagnetic power is modulated, by a 1 kHz square wave. The reception terminal consists in a small $\lambda/2$ dipole test antenna mounted in a rotating plate, with a 360º degrees scale graduated in 5º degree steps, where λ is the wavelength. The $\lambda/2$ dipole reception antenna can be augmented to form a dipole with λ , $3\lambda/4$ and 2λ and the influence of reflector and/or director parasitic elements of antenna arrays with different configurations can also be studied.

The MTS 7.6.5 station supports the study of the radiation pattern of antennas, both on the plane of electrical field or the magnetic field (i.e. horizontal or vertical polarization) or the free space attenuation tests. The first is performed putting the reception antenna at one fixed distance from the emitter and collect data of the voltage (rms value) for several angular orientations within 0º and 360º. The attenuation test consists on collecting data of the voltage values for several distances of the receiving antenna from the emitter. In both tests, the all process was originally operated manually, i.e., the positioning of the reception antenna, the adjustment of its orientation on the rotating plate, the measures, etc. To complete the experiment students had to introduce all data in a spreadsheet software application (e.g. Microsoft Office Excel or Open Office Calc).

Under these conditions, the average amount of time spent to perform a complete radiation pattern experiment is around 30 minutes per group of students, thus allowing up to 6 groups to take measures in a 3-hour session in laboratory. Even for groups of 4 students this represents significant restrictions if one considers the average number of students per class which is around forty, each semester. With these factors in mind, it became clear the need for some significant improvements and for a system for the automation of the MTS 7.6.5 measurement station, capable of collecting data and perform measures from a test setup. Moreover, the objectives and technical requirements were suitable for a 3-year graduation project.

B. Instrumentation Electronics and Computer Organization

The study of computer based instrumentation requires knowledge of computer architecture and organization, its peripherals, I/O addressing and programming skills, besides the knowledge on the operation of the devices. One can study each subject in a separate way and use specific didactic kits for each subject: the operation of Analog to Digital Converters (ADC) and Digital to Analog Converters (DAC) devices, PC internal buses, peripherals and I/O ports, etc.

The major advantage of this approach is the management of the laboratory due to the use the didactic modules in a complementary way by splitting the class in two turns. When the first half uses the ADCs module, the other half uses DAC, and so on. This way only the half of equipments are needed to accomplish with required tasks at laboratory classes. Although the Electronics Lab at EST-IPCB has several didactic modules to help teaching these subjects, they are in general poor in modularity and flexibility, not easy to interconnect and some require an external control unit.

As there were some obsolete PCs with Windows®98 operating system it was decided to use them for supporting units at laboratory classes in an integrated environment as

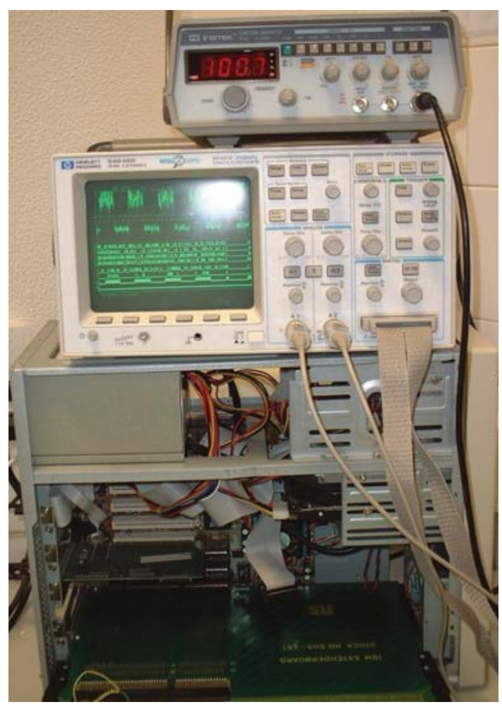


Fig. 2. The integrated environment station: a PC (Windows 98®) with an extender board on the bus (E-ISA), a data analyzer and a frequency counter.

shown in Fig.2, and considered a good alternative solution for the students work and for future expansion on functionalities.

III. Graduation Projects as Aiding Tools

Based on the motivations described above, and pursuing previous work on trans-disciplinary projects [3], the authors proposed and supervised two separate graduation projects to help students at laboratory classes, both requiring hardware/software skills. One project aimed the automation of the antenna measurement station. The other project aimed to help the study of computer architecture and organization, also the practical demonstration of some electronic devices commonly used on instrumentation electronics, using simple and typical applications such as signal generation and data acquisition on a PC via the parallel port.

A. Graduation Project I: Automation of the MTS 7.6.5

The tasks involved in this project include the design of the interface electronic circuits, motor driving, signal conditioning and the assembly and testing of a prototype [4]. The automation system for the MTS 7.6.5 antenna measurement consists of a PC acting as central and control unit, and other functional blocks as depicted in Fig. 3 a). The software application running at the PC controls the stepper motors on the receiver platform, acquires data from the conditioning envelope of the receiver signals through a parallel port and controls all the processes.

The emitter block consists on a power supply of the Gunn oscillator that allows to varying, the -9 V_{dc} medium supply voltage, between -7.5 V_{dc} and -10.5 V_{dc}. This variation can be obtained by a 1 kHz internal square wave oscillator or by external signals (e.g. voice) as depicted in Fig. 3 b), and the radiated power varies proportionally to these. The receiver block consists in a test antenna with a rectifying diode connected for envelop detection (amplitude demodulation), an amplifier with a gain of 1000, and two distinct circuits: one for radiation pattern measurement and the other one for the external signals transmitted by emitter. Finally, an interface circuit samples the signal and converts it to digital with 8-bit words (sample and hold device - S/H and analog to digital converter - ADC) as shown in Fig. 3 c). There is also a circuit for amplifier and loudspeaker to listen the recovered signal when one uses a voice signal at the emitter. The test antenna is mounted in a small platform with wheels, able for translational and rotational movements, actuated by stepper motors for positioning: displacement and rotation. It is possible to place absorbent mats to mitigate any interference due to reflections when measuring the radiation pattern, or to study the influence of these interferences.

Fig. 4 presents a detail of the receiver antenna mounted on the mobile platform and the electronics card for interface and drives for the motors and Fig. 5 shows a snapshot of the software application where it is noticeable an example of antenna radiation pattern and on the left, the values of the voltage measured and acquired for that test. The remaining buttons are for configuration and for test setup. The application also has the possibility to export data in Microsoft Excel (or compatible) files format for further processing.

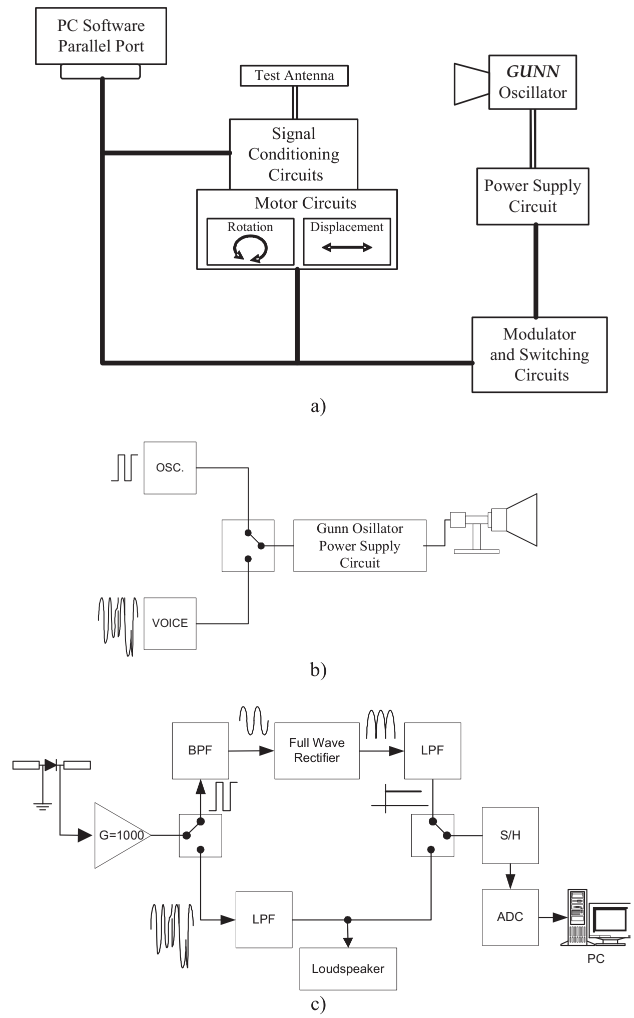


Fig.3 Automation system for the MTS 7.6.5: a) scheme of principle; b) block diagram of the transmitter end and c) block diagram for the receiver end.

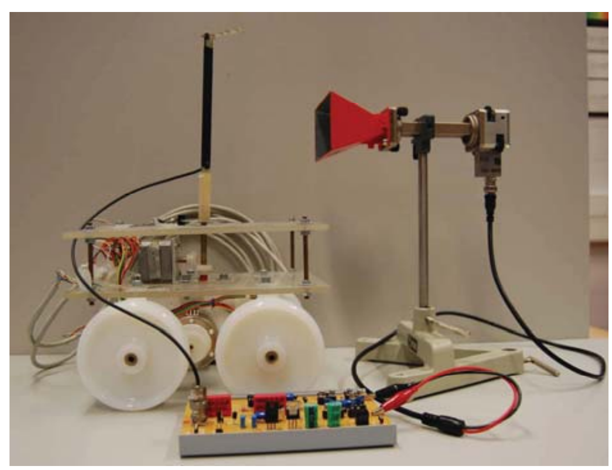


Fig.4. Final assembly: mobile platform with receiver antenna mounted and electronics circuits for motor drives and signal conditioning.

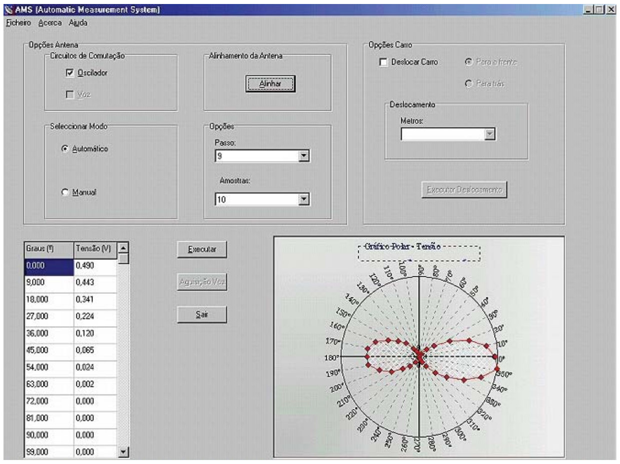


Fig.5. Snapshot of software application: A^2MS (Automatic Antenna Measurement System).

B. *Graduation Project II: PC Based Signal Generation*

This project aimed to help students to study computer architecture and organization, namely for subjects on the operation of internal buses, peripherals, I/O ports, and computer instrumentation electronics devices such as ADC and DAC and also how software interconnects with hardware. For didactic purposes the E-ISA 32-bit [5] bus was chosen and some obsolete PCs with Intel Pentium IV processor and Windows® 98 operating system were used. On the other hand, the signals generators available at the laboratories had mainly a bandwidth up to 2 MHz which was one additional objective: the possibility for low cost signal generators for frequencies above 5 MHz for the three standard signals: sinusoidal, square and triangular waves. The block diagram of the signal generator card is depicted in Fig. 6. The core of the system is the MAX038 Signal Generator IC (manufactured by Maxim Integrated Products, Inc), associated to a DAC IC to control digitally the frequency of oscillation and the duty-cycle. The output frequency is determined by a reference current injected in pin I_{IN} (using a DAC device) and one external capacitor C_{OSC}. For a given current and capacitor it is possible to have an additional adjust on the output frequency within a 70% span through a voltage signal provided by another DAC output. The duty-cycle is also programmable from a voltage, the output amplifiers gains are defined by digitally controlled potentiometers and even the waveform selection is made by changing two bits.

The tasks related to the graduation project consisted on the design of a prototype card to fit into the E-ISA bus whose final prototype assembly is shown in Fig. 7 a) [6]. The hardware module is 16-bit addressable within the range 0300h and 031Fh and fully controlled by a software application with windows-like interface. The software controls two fully independent channels and generates two separate signals, as shown in Fig 7 b) and c). The results obtained exceeded the initial specifications for each channel, allowing the generation of signal within a frequency range from 1 Hz up to 10 MHz, a variation on duty-cycle from 10 to 90%, linear variation on amplitude from 1 to 13 V_{pp}, and the possibility to add a DC component to the signal.

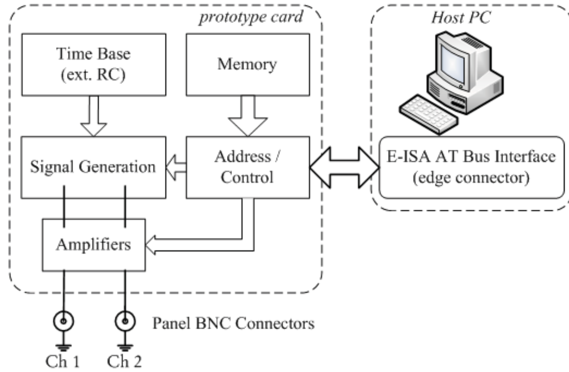
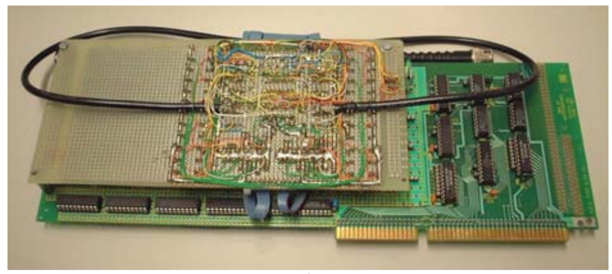


Fig. 6. Conceptual block diagram of the signal generation system.



a)

b)

Fig. 7. The PC based signal generator: a) prototype of the hardware assembly to fit into the E-ISA PC bus and b) snapshot of the application that controls both channels.

Besides its use as signal generator, this prototype help students to study all the steps involved on signal generation process, the organization of the memory spaces on the PC, and the functioning blocks of the hardware prototype card. In order to accomplish with the didactic purposes and facilitate the study of computer architecture, the hardware card can be fitted on an E-ISA bus extender board, in a similar way as that presented in Fig 2. With this solution it is possible to analyze signal activity and data on the computer bus while signals are being generated.

IV. Collaborative Work Experience and Results

The results when carrying both graduation projects were very good as there was a great commitment from the term year students on finding solutions and testing different approaches. One should also point the enthusiasm and good expectations from freshmen students, especially on how it facilitates their work on measuring antennas; also the perception of digital systems, memory spaces, I/O addressing and instrumentation devices, from the practical point of view. Moreover, the PC based Signal Generator can be connected to the Automated Antenna kit system as external signal source thus forming a fully automated test station using a single computer to control all the processes. Although there are commercial solutions available, we preferred this approach not only because of economical reasons, but also due to technical and pedagogical aspects. We consider it as an added value as we gain flexibility on introducing test points on significant stages of the measurement chain; also because we have deep knowledge of the systems and so forth have conditions to improve its functionalities.

The automated antenna measurement system allows a significant cut on time spent with manipulation and repetitive tasks thus avoiding the sense of boring or false useless procedures. As the sequential tests are previously defined and performed automatically, it also avoids errors on measures of voltage signals. With this system the time spent on performing tests was reduced around ~50% thus achieving a significant speed up gain in laboratory classes making possible up at least 10 groups per 3 –hour session. Is also allows an easy way to produce reports on the experiments, namely on graphics, since data is automatically stored in spreadsheet type files. Thus, it is possible to test the behavior of a microwave link under different conditions, and various types of modulating signals and frequencies.

The gain on time to perform these measures and the improvements on accuracy are reflected in a better quality of the radiation pattern. Also provides extra spare time to further analyze the results and interconnect practical results and theoretical concepts, thus leading to better reports on the subject. Besides the use as supporting units to laboratory classes the system is also used for experimental presentations to prospective students at secondary level, in order to attract them to electrical engineering field. Some basic experiences on computer organization and I/O and also on the fundamentals of analog telecommunications are presented and discussed with attendees. The one that most frequently get attention and interest involves a voice signal that modulates a carrier generated by the PC signal generator and transmitted through the microwave link and hear it at the loudspeaker.

The opinion of the students is important in the context of any process within the learning process, so we evaluated their opinions on the degree of satisfaction with the proposed approach. We conducted a brief enquiry with five simple question in what students have to give a rank to its significance within the range from 1 to 5: 1 (very poor), 2 (poor), 3 (fair), 4 (strong) and 5 (very strong). We collected anonymously the answers of twenty (20) freshmen students to the following questions:

Q1 – “Contribution of this approach to enlarge the scope of the learning in general in a multidisciplinary way”;

Q2 – “Importance to the laboratory class with the speed up and improve of the accuracy of the measurements”;

Q3 – “Significance to the laboratory work by the ease of use while avoiding the sense of repetitive and boring tasks”;

Q4 – “Importance of computer based measurement systems and its concepts in the course”;

Q5 – “Contribution to the particular and specific objectives of the course and to the overall skills”.

The results shown in table 1 indicate that the majority of students consider this approach significant in terms of benefits both, to facilitate their work and to strengthening their specific and overall skills. The results in cases of “no opinion” or “no answer” were considered not significant.

At the present there is some work in progress with the objective to upgrade the interconnection of the systems and to add new functionalities, namely the use of USB for communication between the mobile platform and the host PC and the possibility to convert it in a remote lab experience. This way some new subject will be included in the multidisciplinary approach, namely the TCP/IP protocols and services supported on the Web. Students are also being asked to contribute with their ideas, as privileged users, about current functionalities, new aspects and new features that they think are important to include in future releases.

V. Summary

This paper describes an interconnected work experience with two engineering graduation projects and how it can benefit freshmen students as demonstrative of theoretical concepts and also on facilitating their work at laboratory. Both projects form a fully PC based automated test station, namely an Automated Antenna measurement KIT as well a signal generated system.

The experience was very positive as students felt involved with solutions and improvements to the learning process. It also contributes to their skills and expertise on strengthening its concepts in telecommunications and digital electronics. The results obtained are much better compared to the original measurement system and procedures, because it saved time and improved accuracy of the radiation pattern. Another point that deserves to be mentioned is the enthusiasm and expectations from freshmen students, especially on how it could facilitate their work on measuring antennas; also the perception of

Table 1. Results of the enquiry concerning the importance of this collaborative work to the role of the students.

	1	2	3	4	5	No Opin.	No Ans
Q1	0%	0%	15%	35%	45%	0%	5%
Q2	0%	0%	5%	40%	55%	0%	0%
Q3	0%	5%	10%	35%	50%	0%	0%
Q4	0%	5%	30%	35%	20%	5%	5%
Q5	0%	5%	30%	40%	15%	5%	5%

digital systems, memory spaces, I/O addressing and instrumentation devices, from the practical point of view. This system is also used to some demonstrative experiences to attract students to electrical engineering courses.

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FPGA/Embedded System Training Kit Targeted to Graduate Students Towards Industry Level Short Training

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Abstract— **The wide application of embedded systems become a trend in the post-PC era. In the College of Engineering, Universiti Tenaga Nasional (UNITEN), embedded system education is one of the characteristic subjects, so "practical training" is the brand new characters as the most important process in the embedded system education towards industry-geared training. The training is an on-campus process toward gaining the practical experiences which are suitable for the real engineering design or IT related companies, especially so for the students without past work experiences. Practical training using single industrial grade kits on embedded system has expanded to most Electrical and Electronic Engineering for both undergraduate and graduate students. The course has been updated towards industry employees training especially to meet their design aspects. Embedded systems course have been deployed in numerous fields which have different requirements of embedded systems architecture. In this paper, a project-based learning strategy using single training kit is proposed as a pedagogical tool for embedded system education. The proposed project-based learning can motivate students to integrate and formulate the multi-disciplinary knowledge previous learned into a real-world embedded system project development. The course development focused on lecture–lab integration and laboratory learning. Course and lab activities were designed using a learning model that captures lower-order and higher-order cognition levels of Bloom's taxonomy.**

Keywords-Embedded Systems, FPGA, Training KIT, and Graduate education.

I. INTRODUCTION

Many universities offer introductory courses that focus on microcontroller-based systems and embedded programming using different training kits. Advanced courses often do not have a common focus and are not available until the graduate level, leaving a gap in training undergraduates. The courses are integrated through a coordinated set of learning outcomes and the use of related tools and technologies. In addition, the courses are designed with special attention to integrating the lecture and laboratory experiences, making explicit the relationships between lecture topics and laboratory exercises.

A single kit can provide training for various domains such as programming language, digital system (hardware descriptive language) and basic image processing. It comes with an option for future updates. Since the training modules are designed with the objectives to reduce learning efforts and industry relevant, it will benefit many students.

II. COURSE OVERVIEW

The embedded system is a science of the theory and practice regarding as equally important. Figure 1 shows the overview of the course materials related to the training courses. A tutorial course will introduce the domain knowledge and common research issues to students. Programming skills training is necessary when learning embedded systems. It is a good method to practice programming skills through the laboratory (*Lab*). To practice Labs needs an auxiliary tool, *target platform*, a prototype of the hardware of embedded systems. ARM architecture [6] is very popular for embedded system products. The programming skills are necessary skills for advanced research in the future.

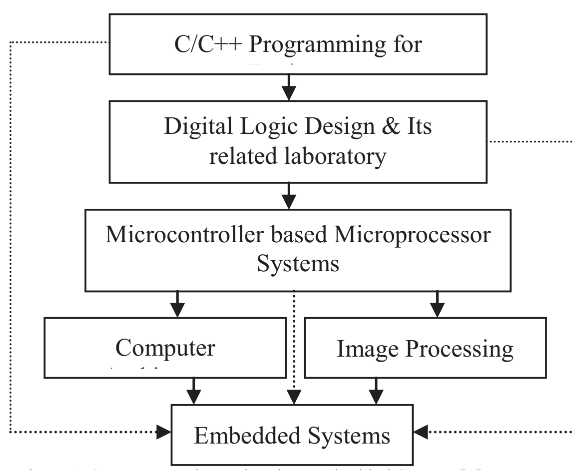

Figure1. Course overview related to Embedded System [1]

Full training course is divided into few sections. Table1 shows the overall structure of the training materials. In embedded C programming, pointers technique, serial communication implementation (UART), interrupt handlers, and image processing is covered. In HDL, combinational logic design, synchronous and asynchronous state machine design, RISC processor design, and custom IP design is included. In SW/HW design, architecture of the soft core and its buses, interfacing with timers IP, UART IP, configurable parallel port, interrupt controller are covered.

TABLE1. CONTAIN OF THE TRAINING COURSES

Embedded "C" Programming	a. Pointers (Accessing content of memory locations) b. Serial communication + Byte Transfer + Array-type Variable c. Ethernet: Send/Receive Data Byte to an IP node d. Interrupt handlers e. Image Processing (algorithms such as depicted in Figure 5)
HDL	a. Combinational logic (examples: decoder, mux, DFF) b. Synchronous state machine / State machine c. Embedded Processor & Hierarchical Buses d. Custom IP cores & Bus Interfaces e. Image Processing (Implementation of algorithms on hardware such as on PLD or FPGA)
HW/SW Co-design	a. Architecture b. Processor Buses & Busses Protocols c. IP cores: 1. Timers 2. Serial Communication 3. Configurable Parallel Port 4. Interrupt Controllers d. Interrupt Handlers/ Processor context switch
System Software	a. Script Linker file, make file b. System timer c. Multitasking & multithreading d. Device Drivers (Device interface, polling/ interrupt driven)

III. PROFESSIONAL ENGINEERING PRACTICE BASED ON PROBLEM SOLVING

Student survey shows that development of student design skill, engineering practice quality, self learning ability, and communication and team work skills, course assignment is not sufficient. Hence, a series of progressive engineering learning skill is necessary. Three stages learning are focused to fulfill all skills. At the first stage, examples based design, which in some extent of a cognitive leaning process is covered. In this stage, students can be experience and have a better knowledge about general hardware design using VHDL, embedded system concepts, design components, design IP, subsystems and design procedures. The aim of the second stage targeted to prepare students with effective use of existing workbench, platform and tools for embedded system design, development and research, and students can grasp how to design, build and troubleshoot an embedded system by existing tools or components based on progressive design and development specification. Student involved in experiential learning emphasized on two section: "simulated" and "authentic" [5]. Simulated experiential learning contains carefully guided learning activities in order to create a specific learning outcome. Authentic experiential learning often made the student engaged in completely open-ended learning and sometimes with limited guidance. Since Engineering practice play important role in embedded system, high level synthesis engineering experiential learning is necessary for students, and the students complete designs within strict hardware design and embedded software programming conventions which are similar to those on which industry engineers are currently working on. In this respects, comprehensive integration design projects is chosen from industry, university-sponsored research, or other practical application environment. Sufficient number of students is made a group so that Working in teams is helpful for building cooperation, leadership, and communication skills which is necessary in student's future work. A cooperative, practical and structured embedded systems design experience was needed in embedded system education. The design experience is based on a problem-based learning approach that motivates student learning and develops skills required by the student in a future professional capacity. Engineering practice should play a more important role in embedded system education. Design software included in training courses included "industrial-strength" features such as real-time, in-circuit debugging and field programmability, and students should be trained to conform to corporate design practices, such as design and coding conventions. The experience can be created, in part, to give students exposure to strict design specifications and the need to follow them faithfully, which is one of the most popular request for an engineering project development.

IV. PRACTICAL TRAINING

The act of rehearsing a behavior over and over, or engaging in an activity again and again, for the purpose of improving or mastering it, as in the phrase "practice makes perfect"[2]. Practical training on embedded system is an on-campus process to gain the practical experiences which are suitable for the real design companies. The propose training interacted between the theoretical courses and the real company practices. Generally, in the design companies, practice means work for the real projects [3]. Even if the work is quite simple, to implement the basic functions or to write the documents, the results will be used into the software products finally. The term training refers to the acquisition of knowledge, skills, and competencies as a result of the teaching of vocational or practical skills and knowledge that relate to specific useful competencies [4]. So, people within many professions and occupations may refer to this sort of training as professional development. The offered embedded system training can be on-the-job or off the-job as the focus on jobs [5]. On-the-job training takes place in a normal working situation, using the actual tools, equipment, documents or materials that trainees will use when fully trained. On-the-job training has a general reputation as most effective for vocational work. Off-the-job training takes place away from normal work situations, implying that the employee does not count as a directly productive worker while such training takes place. Off-the-job training has the advantage that it allows people to get away from work and concentrate more thoroughly on the training itself. This type of training has proven more effective in inculcating concepts and ideas.

To give the clear concepts and the feasible analysis, the relative definitions, such as practice and training, are discussed carefully, and the advantages are carried out.

In Practical Training, the educational philosophy is based on "learning by doing", which means that the practical training heavily focuses on the students actually performing the tasks. Software engineering is a fundamentally practical activity and students find it difficult to see the value of activities without them being placed in a realistic context. The attempt at providing an assignment that has significant similarities to a real-world project.

For the practical training, the courseware has much difference with the common textbooks. The use of courseware according to its design intent: stated learning objectives and audiences, would by definition be the only use the developer can evaluate and assess. The instructors should plan on providing appropriate documentation and understanding of how to evaluate the use of the courseware.

V. Design Examples

Embedded System based practical training to the graduate students towards industry level is focused on Xilinx Microblaze and PowerPC platform integrated system [6]. Figure 2 shows the XILINX hardware architecture to design embedded system. Most of the practical embedded system design for this training materials are used this architecture.

In training materials, few issues are covered which are significant affects on industrial design. At initial stage for beginners trainee, hardware design using FPGAs is covered so that at any stage in peripheral hardware can be designed and interface with processor to achieve expected embedded system. Next stages, standard peripheral hardware available as a Intellectual property (IP) such as USART, BRAM, SRAM and its controller interfacing techniques are trained. In addition, on-chip processor software design using C/C+ for Microblaze soft core processor is covered so that HW/SW design experience can be applicable to the any embedded design company.

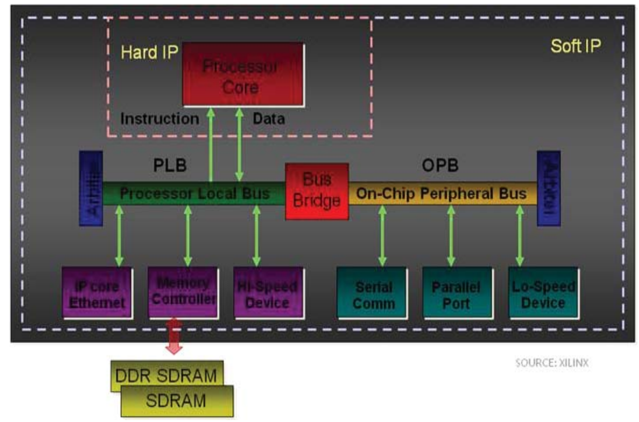

Figure 2. Xilinx embedded system hardware architecture [6]

A. Experimental Setup: On-Chip Game Design

This experimental setup is intended to cover full hardware design using VHDL in FPGA platform. Trainee is given required schematic diagram for the game design. Figure shows the given hardware setup for the light chasing game design. Figure 3 shows the hardware setup using VHDL.

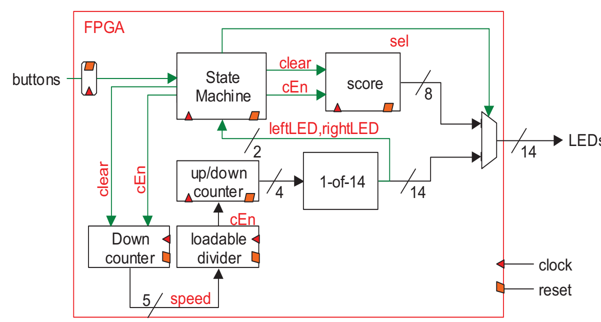

Figure 3. On-chip hardware setup for simple Game design

Trainee will design individual module using VHDL including state machine. After complete all modules, they need to design top-level module to interconnect all modules as required. After complete this module, they will be able to know how to design HW module and controlled by state machine.

B. Experimental setup: Transceiver via Serial Port

This experimental setup is to expose students to interfacing of Universal Asynchronous Receiver Transmitter (UART) to XILINX soft core Microblaze processor. Data transferring over the bus is between two UARTs and saved in pointer variables. The C programming was emphasized for processor.

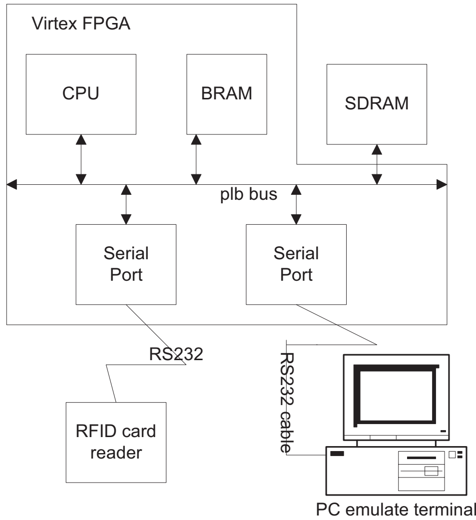

Figure4. Example design of UART interfacing with PLB bus

C. EXPERIMENTAL SETUP: IMAGE PROCESSING

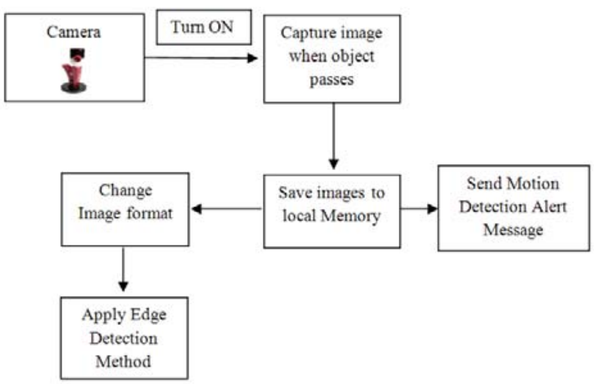

Figure5. Example design of interfacing camera for capturing images and detecting edge

Figure 5 is on the image processing module. The experimental setup is to make camera turn on and capture images when there is a motion. After taking pictures, it is saved on local memory and also sent to alert messaging system through internet and Application Programming Interface (API). The images are needed to convert to portable network graphics format. Then enhanced Sobel edge detection method is applied to detect edges of the images.

VI. STUDENTS RESULTS ON WORKS

Figure 6 shows the students examination results on the course for previous semester. Over three semester evaluation period, most students have able to enhance their understanding, consistent with the excellence examination results and project presentations.

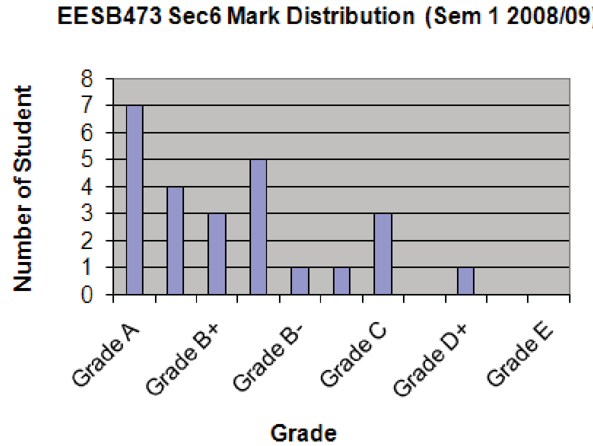

Figure6. Student result on embedded system design course

Figure 7 shows the snap shots of the student project on embedded system. In the picture, students are testing there projects on RFID projects.

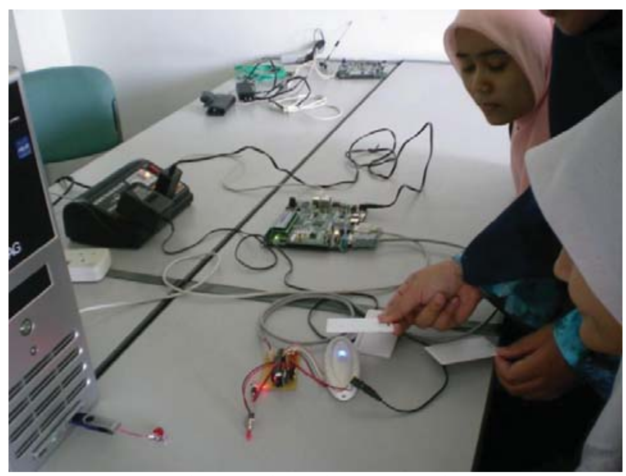

Figure7. Snap shot of student's design project during testing

VII. CONCLUSION

An integrated kit for both hardware and software lesson modules can assist student to grasp difficult abstract concept, thereby improve learning outcomes especially on programming language, microprocessor, digital system. The hardware and software modules include several level of Bloom taxonomy especially to help students to learn difficult concepts toward achieving the synthesis level learning outcome and at the same time expose them to in industrial-grade design environment.

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Educational Software Interface for Power Electronic Applications

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***Abstract*—The design of friendly user tools for power electronics applications is a hot topic among the researchers all over the world. In fact, the digital signal processors programming is a hard task which requires a deep knowledge of the specific hardware platform where the user control program is implemented. In this paper, a user interface for programming digital signal processors (DSP) to control a power electronic converter is presented. The proposed program, called $jscomm$, is currently used as a useful tool to understand how the DSP is programmed, to control a power converter safely and to monitor all the interesting variables of the power converter operation.**

I. Introduction

The simulation and experimental testing of power systems is a fundamental topic of electrical and electronic engineers all over the world [1]–[8]. In this way, different simulation softwares for understanding power electronics have been developed in order to facilitate the teaching in such a difficult topic for new or non-expert students and researchers. As one of the most interesting current simulation tools, the interactive power electronics seminar (IPES) software is a simple educational module dedicated to basic power electronics circuits [9]. Using this tool or other similar, the students can learn the basic operation of many power converter topologies, signal theory in power electronics, pulse width modulation and space vector modulation, etcetera.

On the other hand, recently the e-learning concept has been also successfully applied to the power electronics teaching achieving good results [10], [11]. Using e-learning platforms, the student/researcher can operate a hardware system usually via web. In this way, the user is working with a distant real prototype and is operating it online. The e-learning concept is very useful where a high number of users have to actuate with a single hardware prototype. However, only by simulations or using the e-learning, the students and/or researchers do not actually work with real prototypes and they do not notice the hardware/software problems related with real applications of power converters. They do not see with their own eyes the converter operating, hear the switching noise or work with real power active and passive devices.

In this way, the use of laboratory prototypes especially designed and built for educational purposes is very useful. Using this kind of prototypes, the users are closer to the real power system design dealing with problems such as the power devices sizing, the measuring errors effects, the switching noise, etcetera. Several user tools are required in order to facilitate the interface between novel users and a complex power system formed by the power converter experimental setup, the measuring system and the control hardware (usually a digital signal processor (DSP)). These user tools can be developed by an unique software which implements an interface carrying out all the necessary operations under safe conditions.

II. The proposed user interface ($jscomm$)

In this paper, a friendly user interface for DSP programming and control of power electronic converters is presented. The software, called $jscomm$ has been developed in the Power Electronics Research Group at the University of Seville. The $jscomm$ software is currently being used for post-graduate students in order to develop, test and adjust control techniques for power electronic converters as a part of the required knowledge to get the PhD degree. It is being applied to medium-high power systems but it can be also used for low power applications.

The $jscomm$ software objectives are:

- The $jscomm$ can operate independently of the specific DSP platform by Texas Instruments. In this way, the user can carry out the tests avoiding a deep knowledge of the hardware.
- Using the $jscomm$, the necessary state machine to control a power converter can be easily developed and monitored during its operation.
- The controller of the power converter can be tuned and tested observing the influence of the controller constants on the power converter operation.
- Using the oscilloscope tool present in the $jscomm$, it is also possible to monitor any control or measured variable. This facilitates the user C code debugging finding possible errors in the implemented control techniques.

A. The oscilloscope tool

The $jscomm$ provides an oscilloscope plotting any variable of the power system (the number of channels is configurable). In this way, the operation of the power converter can be monitored online and the implemented control technique can be tested safely. A snapshot of the oscilloscope present in the $jscomm$ is represented in Fig. 1. It is important to notice that not only the physical variables of the prototype can be

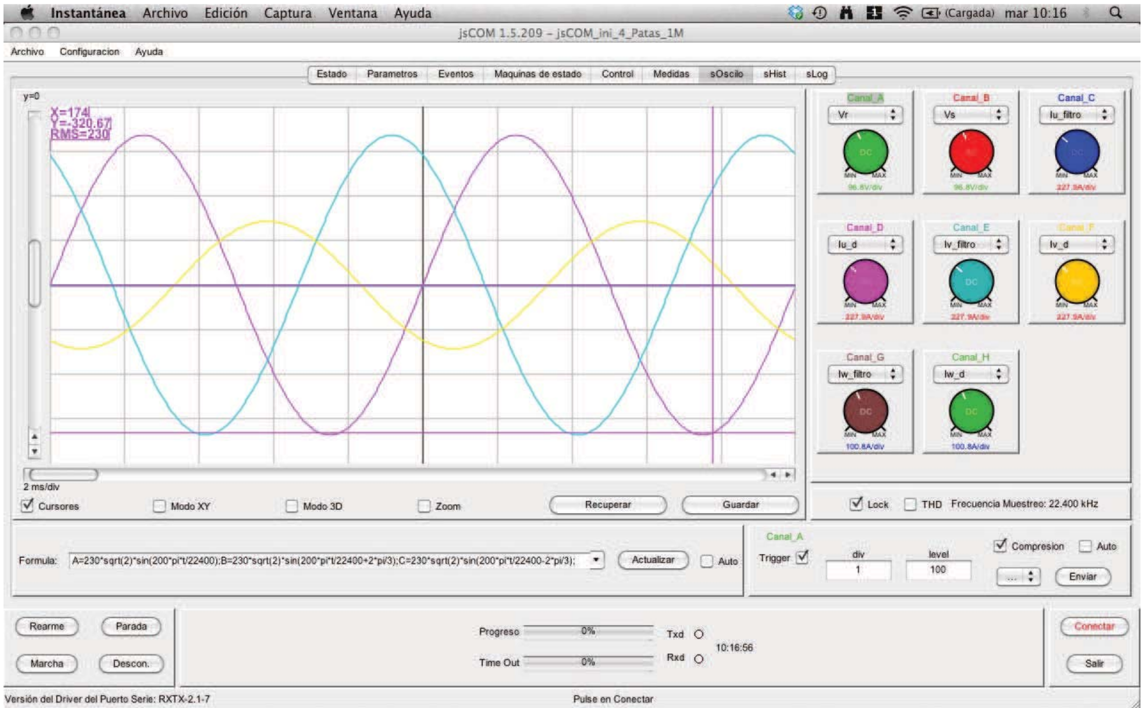

Fig. 1. Eight channels oscilloscope where control or measured variables can be plotted online.

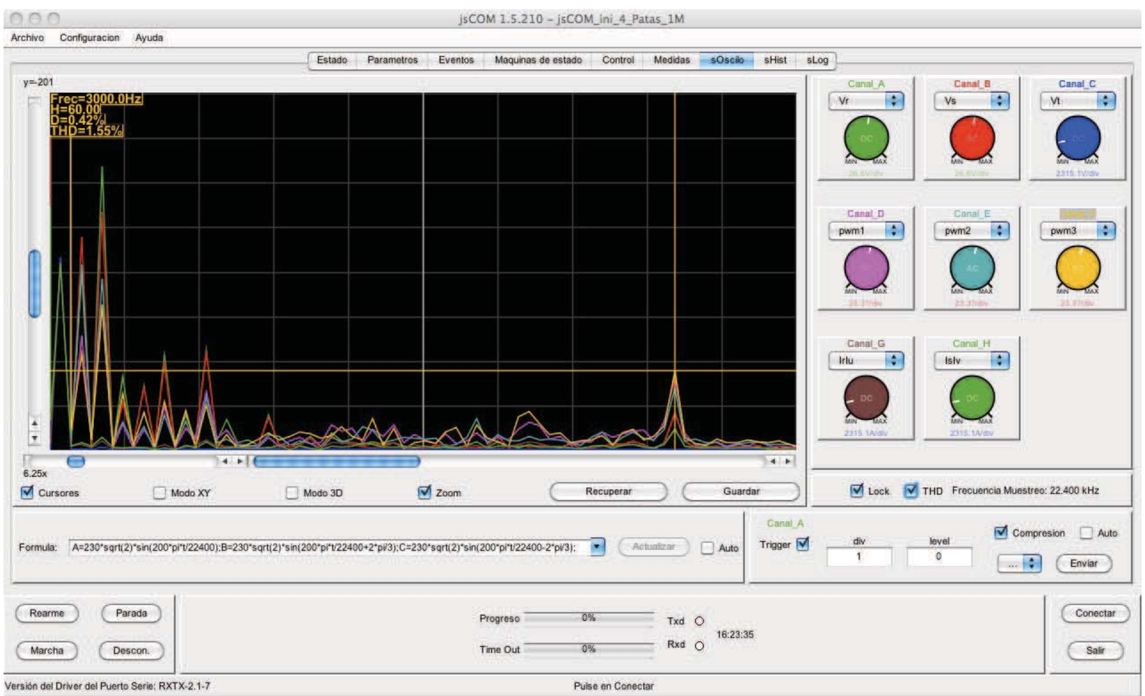

Fig. 2. Oscilloscope tool representing the harmonic spectrum of a measured variable.

represented but also the auxiliary programming parameters. This capability for tracing any DSP control program internal variable facilitates the debugging procedure and the understanding of the power converter behavior. The oscilloscope tool provides important information such as the RMS value and the average value of each channel. As usual oscilloscopes,

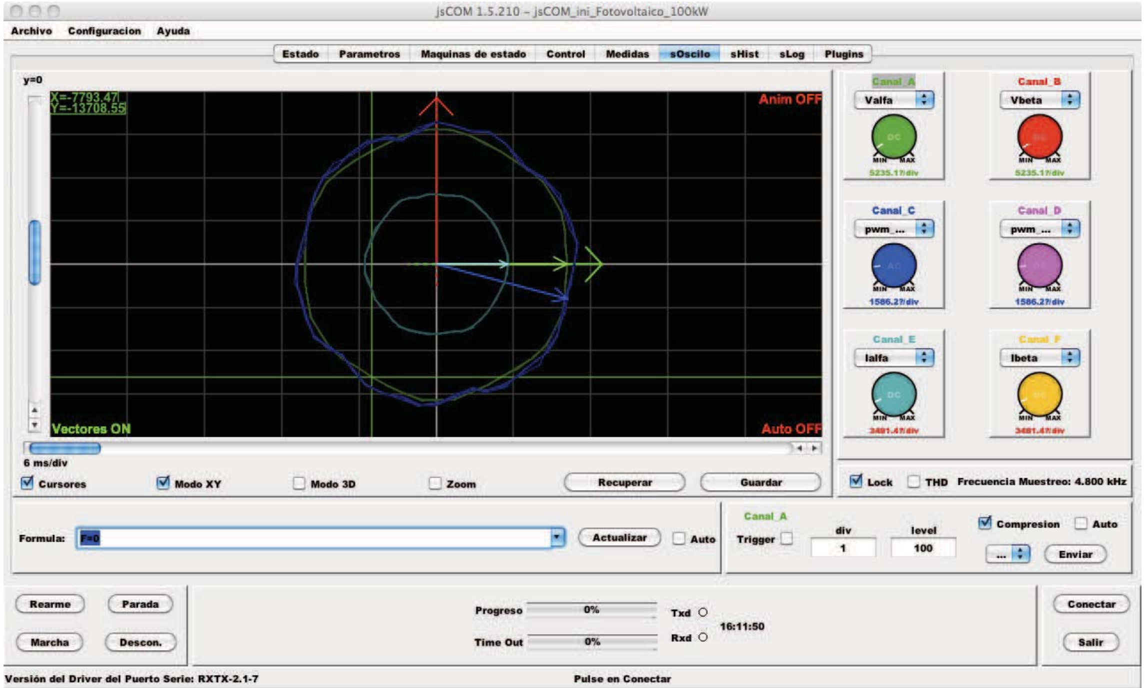

Fig. 3. Oscilloscope tool configured in the XY representation mode.

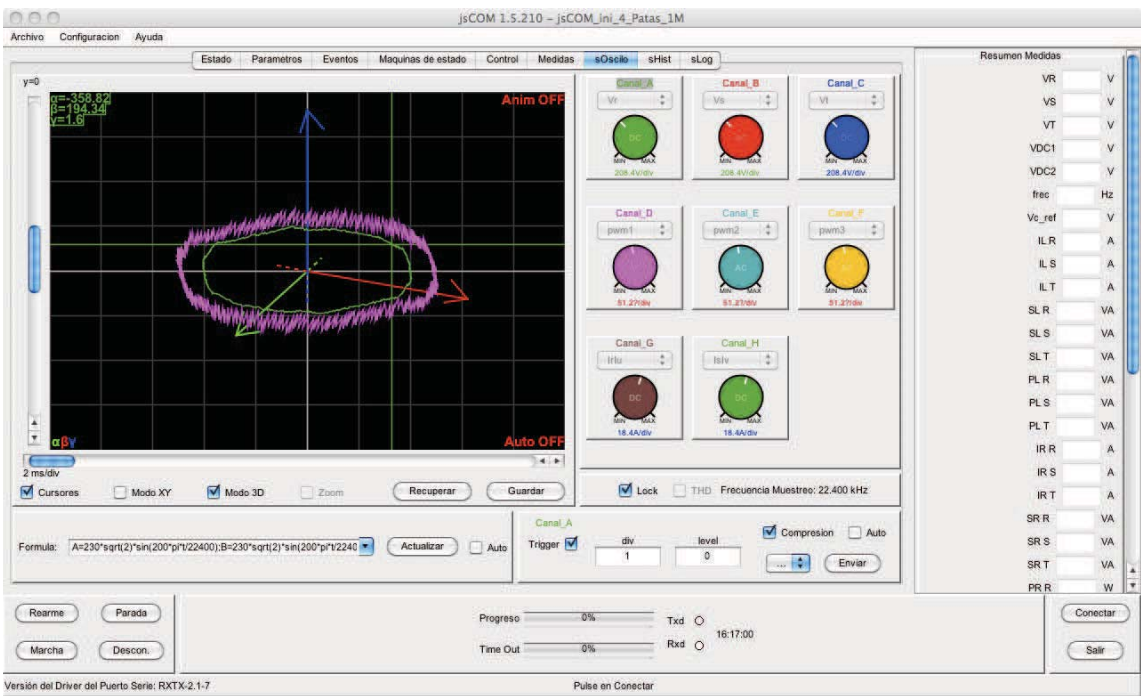

Fig. 4. Oscilloscope tool configured in the three-dimensional representation mode.

it provides the trigger function which is useful to capture the waveforms when a condition is fulfilled. In addition, the volts/div, amp/div and time/div in the $jscomm$ oscilloscope have exactly the same functionality compared with real oscilloscopes. As an additional function, it is possible to carry out mathematical operations using the oscilloscope channels as a sum, subtraction, multiplications, etcetera. In this way, it is possible to calculate operations such as A=A+B-C+3*D for instance (where A, B, C and D are the four first oscilloscope channels). Besides, as an additional functionality, the harmonic spectrum can be also plotted providing important information for power systems and this is shown in Fig. 2.

Finally, two representation options can be defined in the $jscomm$ oscilloscope tool. Firstly, the XY representation mode can be defined representing channel A versus channel B. The XY representation mode is useful in power electronics system to represent variables in alfa-beta coordinates. A representation of the $jscomm$ oscilloscope working in XY mode is shown in Fig. 3 where a phase current of a power converter is represented in the alfa-beta plane representing the beta current versus the alfa current. Secondly, a three-dimensional representation mode can be also chosen. In this way, three different channels can be represented and it is useful to represent for instance the phase currents of the power converter in in a cartesian coordinates frame. The three-dimensional representation mode is shown in Fig. 4 where the phase currents of a three-phase power converter are plotted. These two representation modes help to the user to understand how the power converter is operating and the influence of the controller on the power converter operation. Finally, it has to be noticed that these representations are plotting information continuously using a trail to represent past samplings as can be observed in Fig. 3 and Fig. 4.

B. The states diagram tool

One of the most interesting characteristics of the $jscomm$ is that it includes a tool for developing a states machine to control the power system. The states machine is plotted using a classical diagram where the states are represented using balls and the conditions to carry out the transitions between the states are defined using arrows. As a Moore machine is implemented, each state has defined outputs and the transitions are combinations of the inputs or other conditions written on each arrow. The transitions can be defined as:

- User commands such as $stop$ or $connect$ related to buttons present in the $jscomm$ user screen.
- Measurements such as the dc voltage, excessive phase currents, emergencies, etcetera.
- A time condition defining therefore transitory states.
- A combination of the previous ones.

An example of the generation of the states machine for a conventional three-phase power converter rectifier is represented in Fig. 5.

It is very important to notice that the states machine diagram, developed by the user with a very friendly software interface, directly generates the corresponding C code to be implemented in the DSP. In this way, the generation of the states machine, needed in most of the power system applications, is simplified. In fact, the use of the states machine diagram avoids design errors and, during the converter operation, the state where the converter is working each moment is highlighted.

C. The calibration tool

An important topic of the power conversion is the calibration of the voltage and current sensors. This issue has to be carried out minimizing the possible measuring errors and the

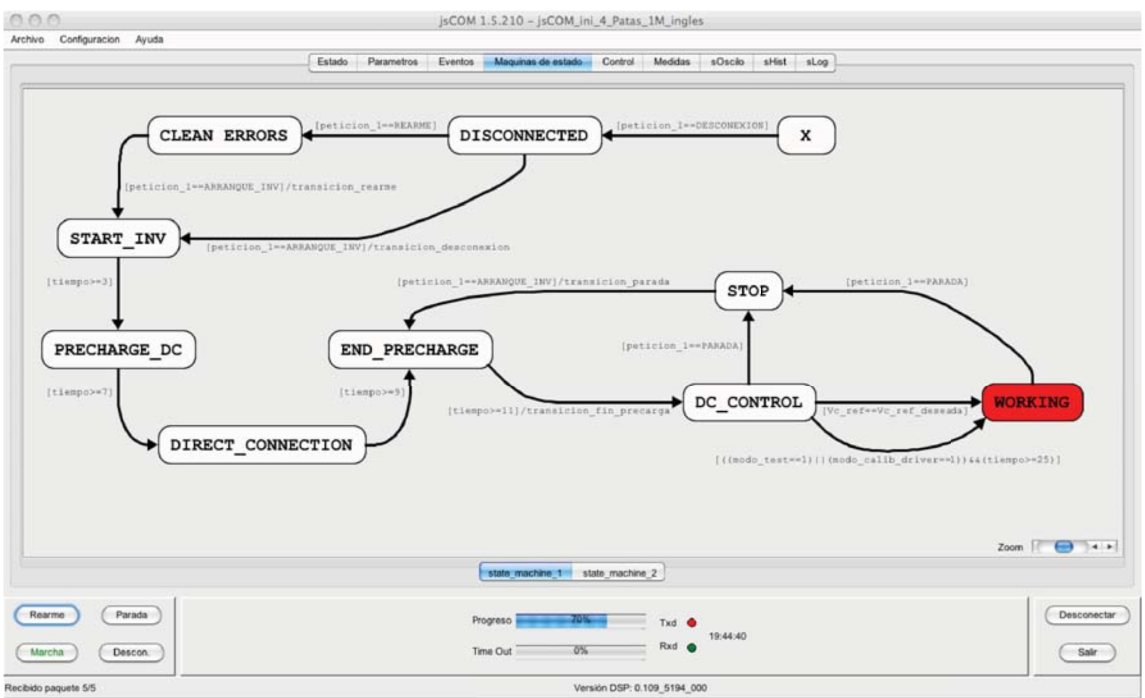

Fig. 5. States machine screen where the possible states and the transitions are defined.

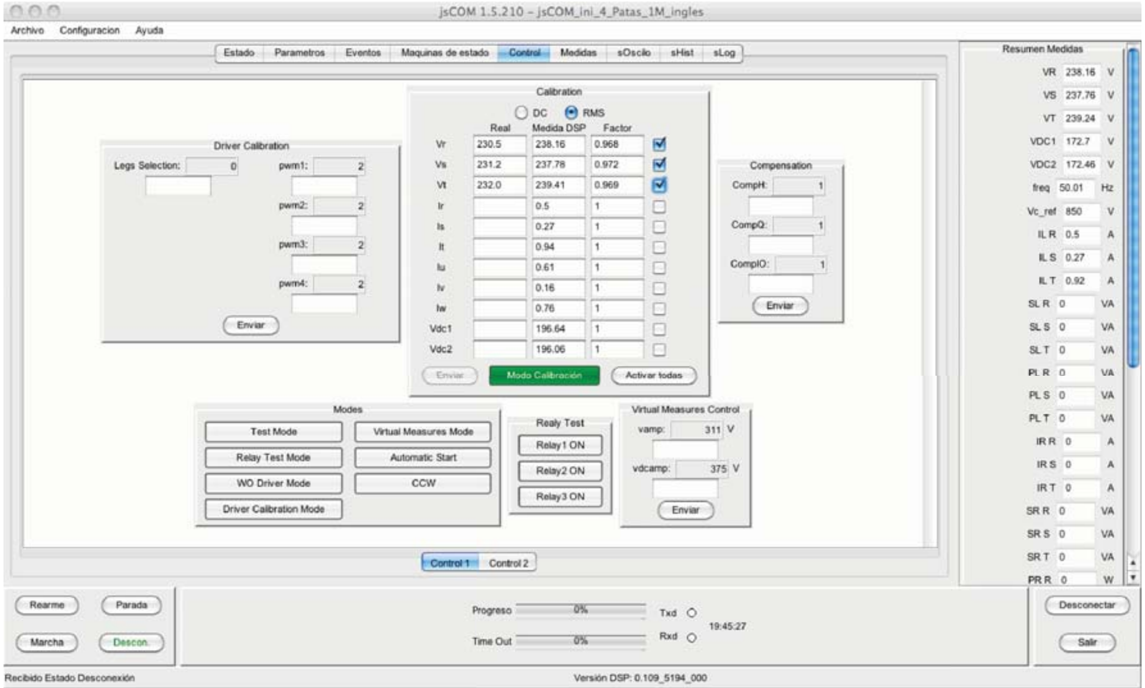

Fig. 6. Calibration tool where the measurement adaptation parameters are determined to reduce the calibration errors.

Fig. 7. Controller screen where the tuning of the controller constants can be done.

$jscomm$ software provides an automatic calibration tool to solve it. All the measurements of the power system can be calibrated online. The user has to introduce in the $jscomm$ calibration screen the actual value of the measurement and execute the automatic self-calibration tool. The self-calibration procedure calculates the measurement adaptation parameters to reduce the measurement errors. Finally, once the power converter sensors have been calibrated, the measurement adaptation parameters can be saved in a file for next experiments. In this way, the calibration procedure has to be executed only the first time and it is not necessary to repeat all the process. The $jscomm$ calibration tool is represented in Fig. 6.

D. The controller adjustment tool

The design of high performance controllers for power converters is a hard task for non expert students/researchers. A lot of efforts are usually spend on the adjustment of the controller parameters and the determination of the dynamic and steady-state behavior of the power system. Typically the optimal controller parameters do not coincide with those optimal for the real prototype due to small differences such as voltage drops, losses, passive device tolerances, noise, calibration errors, etcetera. In this way, it is always necessary a tuning procedure to obtain the best possible performance of the power converter.

The $jscomm$ users can design any control technique to be implemented in the power converter. The $jscomm$ permits to change the values of the controller constants during the operation of the converter making easier the controller constants tuning process. This fact can show the impact of any term of the controller on the performance of the control variables. For instance, considering a classical controller where an external voltage control loop and an internal current control loop are used, the influence of the proportional, integral and derivative PID controllers on the dc voltage or the phase currents can be measured. This can help to novel power control researchers to understand the operation of the power converter and the controllers design. A snapshot of the controller adjustment tool present in the $jscomm$ software is presented in Fig. 7.

E. The emergency management tool

An special attention has to be paid on the emergencies management. The main concern in a educational power system is the safety and all the possible emergencies have to be taken into account. This emergency could be an overvoltage, overcurrent, minimum voltages in the dc side, driver errors, communication errors, etcetera. If an emergency happens, the $jscomm$ software stops the power system operation and shows the emergency cause to the user highlighting the corresponding flag in the emergency tool. This tool is shown in Fig. 8.

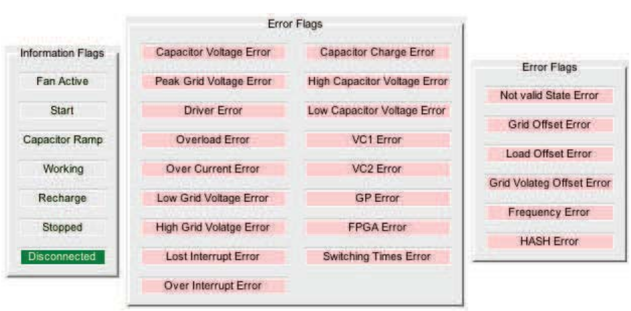

Fig. 8. Emergency tool showing the possible emergencies in the power system.

F. Auxiliary $jscomm$ tools

Some extra functionalities have been added to the $jscomm$ program. These auxiliary tools are:

- FFT calculation.
- Data compression in the communication between the DSP and the $jscomm$.
- Log file generation including a historical information about all the operations carried out in a $jscomm$ session.
- Flash memory programming.

III. Conclusions

In this paper, a user interface, called $jscomm$, for programming digital signal processors (DSP) to control a power electronic converter is presented. The $jscomm$ software is currently being used for post-graduate students in order to develop, test and adjust control techniques for power electronic converters as a part of the required knowledge to get the PhD degree. All the tools provided by the $jscomm$ program have been introduced during the manuscript.

Acknowledgment

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Session 06B Area 3: Specific Engineering Disciplines - Practical projects in Engineering

Practice and Research in Engineering Education: Activities of the CESEI Technical Committee

Arcega-Solsona, Francisco; Carpio, José; Castro-Gil, Manuel Alonso; Díaz, Gabriel; Domínguez, Manuel; Falcone, Francisco; Jurado, Francisco; Mur, Francisco; Pastor, Rafael; Plaza, Inmaculada; Sánchez, Francisco; Sánchez-Ortiz, José Ángel; Tovar, Edmundo

IES Gonzalo de Castro (Spain); Spanish University for Distance Education-UNED (Spain); Technical University of Madrid-UPM (Spain); University of Jaén (Spain); University of León (Spain); University of Navarra (Spain); University of Vigo (Spain); University of Za

A Practical Electronic Instrumentation Course for Engineering Students

Alonso-Fernández, Fernando; Ramos, Daniel

Autonoma University of Madrid (Spain)

Teaching Microprocessors Design Using FPGAs

Gámez, Juan Carlos; Olivares, Joaquín; Palomares, José Manuel; Soto, José Manuel

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Development of a Small Radio Telescope at the Technical University of Cartagena

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Practice and Research in Engineering Education

Activities of the CESEI Technical Committee

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Abstract—**This paper shows the activities of the Technical Committee of the CESEI (Spanish Chapter of the IEEE Education Society). The CESEI is focused on the development of the education in engineering, mainly Electric and Computer Engineering, and the Technical Committee is devoted to contribute to its awareness and dissemination. As in other interdisciplinary fields, the engineering education field involves several sources of information and different stakeholders, each one with its own focus and purpose. As a result, sometimes it may be complex for practitioners and researchers to identify the more appropriate entities for their interests. The CESEI Technical Committee tries to solve this difficulty by providing updated information about the main publications (journals), events (conferences), organizations and other elements of interest.**

Keywords- e-learning publications, e-learning research

I. INTRODUCTION

Engineering education has risen as a global discipline during the last decades [1]. As a discipline it is usually considered multidisciplinary, involving particular topics of the engineering domains (electrical, computer, civil), social, legal and business issues, in addition to general education concerns. At this point, a common criticism to the consideration of engineering education as a discipline is that education researchers could better solve engineering education problems. Anyway, the teaching and learning of engineering has captured so much attention that it is a discipline on its own.

Nowadays there exists a large scientific community supporting the engineering education discipline. At engineering universities and schools it is very common to find researchers and research groups working on engineering education problems. Many engineering companies also have created groups to work on these topics in the context of life-long learning or career development programs. At a higher level, persons, groups and companies are joined into national and international associations whose main purpose is to work towards the development and empowering of this discipline. These organizations sponsor a large number of events and publish journals and books focused exclusively on engineering education problems. Some of these events and journals have been assessed as very relevant by main research indexes.

This interest on engineering education is also present in one of the most important engineering associations: the IEEE. The IEEE is the world's leading professional association for the advancement of technology. The IEEE name was originally an acronym for the Institute of Electrical and Electronics Engineers, Inc. Today, the organization's scope of interest has expanded into so many related fields, that it is simply referred to by the letters I-E-E-E (pronounced Eye-triple-E) [2]. IEEE includes many unique technical organizations, active in the areas or publications, conferences and building technical communities. Among these organizations, the Education Society (EdSoc) was created with the main aim of "*shall be scientific, literary, and educational in character. The Society shall strive for the advancement of the theory and practice of electrical and computer engineering and of the allied arts and sciences, and the maintenance of a high professional standing among its members and affiliates, all in consonance with the Constitution and Bylaws of the IEEE and with special attention to such aims within the field of interest of the Society*" [2]. His fields of interest are: "*Educational Methods, Educational Technology, Instructional Materials, History of Science and Technology, and Educational and Professional Development Programs within Electrical Engineering, Computer Engineering, and allied disciplines*" [2].

In 2004, it was created the Spanish Chapter of the Education Society of the IEEE (from now on CESEI). The CESEI has the same fields of interest and aims that the IEEE EdSoc has. Nevertheless, the CESEI is focused in Spain and in the Spanish tongue area [3]. Inside the CESEI several Technical Committees were created CESEI [4], one of them devoted to the dissemination and awareness of the engineering education field.

The final goal of the CESEI is to promote the development of this discipline supporting practitioners and researchers. To contribute to this goal the Technical Committee provides updated information about relevant conferences, journals and organizations. We consider this information very useful for professionals and researchers, because it is offered a clear picture of the main actors involved and the key sources of information. This paper is produced as a contribution to this effort, including an updated and complete compilation of engineering education associations, conferences and journals at world and Spanish levels.

II. Practice in Engineering Education

Typically, engineering education is organized along disciplinary lines. In the US and Western Europe one often finds engineering departments with titles such as Civil Engineering, Chemical Engineering, Computer Engineering, Electrical Engineering, Industrial Engineering, etc. The curriculum on these departments is usually made up by two years of education in fundamentals (mostly mathematics and physics), followed by disciplinary education within the confines of their specialized faculty and facilities. In some cases, students are offered with additional courses in social, business and legal sciences. These, however, are seldom integrated with the engineering curriculum in a manner that enhances the disciplinary knowledge or the practice of engineering techniques.

The specialized nature of engineering education runs contrary to the increasing need to prepare engineers for multidisciplinary and interdisciplinary work. In the real world, engineers often work in teams with other engineers and non-engineers with a wide range of specializations. The engineering process thus almost always transcends the particular engineering discipline and requires a much broader ”holistic” view. Moreover, the engineering workplace has undergone significant changes in the last decades. Nowadays, almost all engineers depend on networking and computing tools. In this way, engineering education needs to extend beyond technical and scientific aspects, involving the master of issues such as:

- The ability to effectively communicate in written and oral forms.
- A set of business capabilities, practices and awareness. This includes understanding of marketing, economics and organizational management, their interplay among themselves and with the engineering process.
- An understanding for and work ethic for leadership in the workplace, individual and team contributions, sensitivity to customer needs, their incorporation into the engineering and engineering management process, and commitment to the concepts of total quality management.
- A sense of professional, ethical and legal responsibilities.
- An appreciation of the joy of learning and of the need for lifelong learning.
- An appreciation for intellectual breadth to be not only an engineering leader but a well versed and updated participant in societal activities. To reach this requires an appreciation for the humanities, arts, politics, law and business beyond that which is technically or scientifically targeted.

As the engineering curriculum is altered, it must be also addressed how we teach and learn it. In Europe, the Bologna Declaration signed in 1999 has accelerated these changes and new degrees have appeared. On the other hand, those changes have promoted a deeper interest on methodology, considering issues such as: how faculty interact with students, how students learn, and how emerging technologies are embedded into the educational environment making it more exciting and more effective.

III. Research in Engineering Education

Engineering education has become field of scholarly research in its own right. The past engineering education practices based on the transfer of knowledge, experiences and beliefs are no longer sufficient. Globally, engineering education is on the agenda for solving important issues for the future of engineering education, such as recruitment of students to engineering programs, the need for new competences and the ability to deal with new types of interdisciplinary and complex knowledge. More over, these changes have to be performed in accordance with sound research. This turn towards a more research-based approach is sustained by the growth in conferences, journals and publications dedicated to engineering education. The problem at this point is to get a clear picture of the main actors involved in this discipline: who are the more important associations? What are the best journals? Which is the most appropriate conference to publish a kind of research? These are some of the questions that users in the engineering education domain could be asking themselves. This section provides an excerpt of the main actors on this domain to solve them.

A. Engineering Education Associations

Associations focused on engineering education are spread worldwide. In this section we show the more important ones, taking into account their dimension, research relevance and international dimension. Table I includes key data together with the main conferences and journals supported by them. These conferences and journals are introduced in the following sections. Next it is provided a brief comment about the goals and scope of each of one of these associations:

- AACE is “*an international, not-for-profit, educational organization with the mission of advancing Information Technology in Education and E-Learning research, development, learning, and its practical application*”.
- ACM SGICSE mission statement is “*to provide a forum for educators to discuss issues related to the development, implementation, and/or evaluation of computing programs, curricula, and courses, as well as syllabi, laboratories, and other elements of teaching and pedagogy*”.
- AIED is “*an interdisciplinary community at the frontiers of the fields of computer science, education and psychology*”. It promotes research and development of interactive and adaptive learning environments for learners of all ages, across all domains. Its goal is “*to advance knowledge and promote research and development in the field of artificial intelligence in Education*”.

- APSCE objective is "*to promote the conduct and communication of scientific research related to all aspects of the use of computers in education, especially within the Asia-Pacific*".
- ASEE is "*a nonprofit organization of individuals and institutions committed to furthering education in engineering and engineering technology*".
- The IEEE CS is "*the world's leading organization of computing professionals and the largest of the 38 societies of the IEEE*". This society is dedicated "*to advancing the theory and application of computer and information-processing technology*".
- The IEEE ES fields of interest are "*the theory and practice of education and educational technology involved in the effective delivery of domain knowledge of all fields within the scope of interest of IEEE*".
- The IEEE LT is a technical committee of the IEEE CS. It has as a purpose "*to contribute to the field of advanced learning technologies*".
- The IFEES is and international society that groups to 48 member societies and companies. This association is working to establish effective engineering education processes of high quality around the world. Its final goal is "*to assure a global supply of well-prepared engineering graduates*".
- IGIP is working in cooperation with other associates dedicated to engineering education, such as SEFI and IFEES, "*to support the development of engineering education*". It has working groups in curriculum development, international aspects of engineering education, knowledge management and computer-aided technologies, languages and humanities in engineering education, mathematics and natural sciences in engineering education, people and technology, postgraduate education and qualifications framework, technical teacher training, women in technical careers, and working with projects.
- SEFI is the largest network of higher engineering institutions and of individuals involved in engineering Education in Europe. SEFI aims are "*to develop information about engineering education, to improve communication and exchange between professors, researchers and students and to promote cooperation between the various institutions concerned with engineering Education*". It maintains WGs on the following issues: Curriculum Development, Continuing Engineering Education, Mathematics, Information and Communication Technologies, Gender and Diversity, Physics and Engineering Education, Ethics in Engineering Education, and Engineering Education Research.

TABLE I. MAIN ENGINEERING EDUCATION ASSOCIATIONS

Acronym	***Full Name***	***URL***	***Main Conferences***	***Main Journals***
AACE	Association for the Advancement of Computing in Education	www.aace.org	ED-MEDIA	-
ACM SIGCSE	ACM Special Interest Group on Computer Science Education	www.sigcse.org	ACE, ICER, ITiCSE, ITS, SIGCSE	Transactions on Computing Education Inroads – SIGCSE Bulletin
AIED	International Society for Artificial Intelligence in Education	ihelp.usask.ca/iaied/ijaied/aiedsoc.html	AIED, ITS	International Journal of Artificial Intelligence in Education
APSCE	Asia-Pacific Society for Computers in Education	www.apsce.net	ICCE	-
ASEE	American Society for Engineering Education	www.asee.org	FiE	Journal of Engineering Education
IEEE CS	IEEE Computer Society	www.computer.org/portal/web/guest/home	FiE, ICALT, ITS	Journal of Educational Technology & Society IEEE Transactions on Learning Technologies
IEEE ES	IEEE Education Society	ewh.ieee.org/soc/es	FiE	IEEE Transactions on Education IEEE Transactions on Learning Technologies IEEE Multidisciplinary Engineering Education Magazine
IEEE LT	IEEE Technical Committee on Learning Technology	lttf.ieee.org	ICALT, ITS	Learning Technology Newsletter
IFEES	International Federation of Engineering Education Societies	www.ifees.net	-	-
IGIP	International Society for Engineering Education	www.igip.org	-	Journal of Engineering Edcuation
ISLS	International Society of the Learning Sciences	www.isls.org	CSCL	International Journal of Computer-supported Collaborative Learning
SEFI	Société Européenne pour la Formation des Ingénieurs (*European Society for Engineering Education*)	www.sefi.be	-	European Journal of Engineering Education

It is interesting to provide some more information about IFEETS to highlight the large number of associations focused on engineering education worldwide. Some of the member societies are (see Table I): ASEE, IEEE, IGP and SEFI. The rest of member societies are shown on Table II. This table includes associations of the majority of developed countries. In addition, there are several companies that are members: *Agilent Technologies, India* (www.home.agilent.com); *Autodesk* (www.autodesk.com); BOEING (www.boeing.com); *Dassault Systemes* (www.3ds.com); *Hewlett-Packard Company* (www.hp.com); *Infosys* (www.infosys.com); *SAE Brasil* (www.saebrasil.org.br); *Scalable Network Technologies* (www.scalable-networks.com); *Siemens* (www.siemens.org) and *The Math Works* (www.mathworks.com). The *Journal of Engineering Education* (see Table IV) is also a member.

TABLE II. SOME OF THE IFEES MEMBER SOCIETIES

Name	*Area*
Asociación Colombiana de Facultades de Ingeniería	Colombia
African Engineering Education Association	Africa
African Network of Science and Technical Institutions	Africa
Asociación Nacional de Facultades y Escuelas de Ingeniería	Mexico
Associacao Brasileira de Ensino de Engeniharia	Brasil
Australasian Association for Engineering Education	Australia and surroundings
Board of European Students of Technology	Europe
Cartagena Network of Engineering	-
Chinese Society for Engineering Education	China
Council of Deans Engineering Faculty of Chile	Chile
Council of Engineering Deans of Thailand	Thailand
Council of Research in Education and Sciences	Brasil
Engineers Canada / Canadian Engineering Accreditation Board	Canada
Engineering Council of South Africa	South Africa
Engineers for a Sustainable World	-
Engineering for the Americas	America
European Network for Accreditation of Engineering Education	Europe
Federal Council of Deans of Engineering of Argentina	Argentina
German Accreditation Agency Specialised in Accrediting Degree Programs in Engineering, Informatics, the Natural Sciences and Mathematics	Germany
Ibero-American Association of Institutes of Engineering Education	America, Spain, Portugal
Indian Society of Technical Education	India
Indo-US Collaborative for Engineering Education	India, USA
The Institution of Engineers, Singapore	Singapore
Instituto Superior de Engenharia de Lisboa	Portugal
The International Association for Continuing Engineering Education	-
Japanese Society for Engineering Education	Japan
Kazakhstan Society of Engineering Education	Kazakhstan
Korean Society of Engineering Education	Korea
Korean Society of Semiconductor Equipment and Technology	Korea
Latin American and Caribbean Consortium of Engineering Institutions	Latin America and Caribbean
Núcleo de Decanos de Ingeniería de Venezuela	Venezuela
Russian Association for Continuing Engineering Education	Russia
Russian Association for Engineering Education	Russia
Student Platform for Engineering Education Development	
Turkish Engineering Deans Council	Turkey
Unión Mexicana de Asociaciones de Ingenieros	Mexico
Upsilon Pi Epsilon International Honor Society for the Computing and Information Disciples	-
World Federation of Engineering Organizations, Committee on Capacity Building	-

B. Engineering Education Conferences

As other research disciplines, there exists a plethora of events (conferences, symposiums, workshops) where it is feasible to publish research works about engineering education. Moreover, many times the research works in engineering education are multi-disciplinary and in this way it is possible to publish them in several scopes. Anyway, there are also specific conferences more specially focused on engineering education.

Table III includes a list of the main events related with engineering education. The data provided for each event is the acronym, full name, involved associations, (geographical) area, first year edition, scheduled (annual or bi-annual character and months of the year in which it is celebrated), and classification in accordance with the CORE index. The first issue to notice is that there are some conferences with a history of near 40 years. Meanwhile, there are other conferences much more recent, some of them with an existence of 5 or 6 years. In relation with the geographical area there are localized conferences in the main continents except in Africa. The other conferences usually vary their localization from continent to continent.

To classify these events one of the more important research indexes is used. The Computer Research and Education of Australasia (CORE [1]) is an association of university departments of computer science in Australia and New Zealand to assist and advance research in computer science and information technology. In January 2008 this association published a ranking of ICT conferences classifying them in accordance to the quality of the papers into five tiers:

- Tier A+. Typically, a tier A+ conference would be one of the very best in its field or subfield in which to publish and would typically cover the entire field/subfield. These are conferences where most of the work is important (it will really shape the field), where researchers boast about being accepted, and where attendees would gain value from attending.
- Tier A. Publishing in a Tier A conference would add to the author's respect, showing they have real engagement with the global research community and

[1] http://www.core.edu.au Last access on November 2009.

that they have something to say about problems of some significance. Attending a Tier A conference would be worth travelling to if a paper was accepted.

- Tier B. This covers conferences where one has some confidence that research was done, so publishing there is evidence of research-active status (that is, there is some research contribution claimed, and a program committee that takes its job seriously enough to remove anything ridiculous or ignorant of the state of the art), but it's not particularly significant.
- Tier L. These are local conferences, which may be important for the social cohesion of the local community and for networking.
- Tier C. All the rest.

In this section we have just shown conferences in the tiers A+, A and B. There exist much more conferences related with engineering education in tiers L and C. Anyway, as it has been described, the relevance of these conferences from a research point of view is smaller.

TABLE III. MAIN ENGINEERING EDUCATION CONFERENCES

Acronym	*Full Name*	*Involved Associations* [a]	*Area*	*First Year Edition*	*Scheduled* [b]	*CORE* [c]
CSCL	Computer Supported Collaborative Learning	ISLS	-	1995	B (May-July)	A+
AIED	International Conference on Artificial Intelligence in Education	AIED	-	1981	B (May-July)	A
ICALT	International Conference on Advanced Learning Technologies	IEEE CS, IEEE LT	-	2001	A (June-July)	A
ICER	International Computing Education Research Workshop	ACM SIGCSE	-	2005	A (August-October)	A
ITiCSE	Annual Conference on Innovation and Technology in Computer Science Education	ACM SIGCSE	Europe	1996	A (June-August)	A
ITS	International Conference on Intelligent Tutoring Systems	ACM SIGCSE, AIED, IEEE CS, IEEE LT	-	1988	B (June-September)	A
SIGCSE	ACM Technical Symposium on Computer Science Education	ACM SIGCSE	USA	1969	A (February-March)	A
ACE	Australasian Conference on Computer Science Education	ACM SIGCSE	Australia and surroundings	1996	A (December-January)	B
ED-MEDIA	World Conference on Educational Multimedia, Hypermedia and Telecommunication	AACE	-	1987	A (June-July)	B
FiE	Frontiers in Education Conference	ASEE, IEEE CS, IEEE ES	USA	1971	A (October-November)	B
ICCE	International Conference On Computers in Education	APSCE	ASIA-Pacific	1989	A (October-December)	B
InSITE	Informing Science and IT Education Conference	ISI[d]	-	2001	A (June)	B
Koli Calling	Baltic Sea Conference on Computing Education Research	-	Baltic Sea Countries	2001	A (October-November)	B

a. See section III.A for more information about main associations in education engineering

b. Scheduled distinguishes between A (Annual) and B (bi-annual) conferences

c. Classification in the Australian Ranking of ICT Conferences

d. *Informing Science Institute* (informingscience.org)

C. *Engineering Education Journals*

This section includes some journals publishing papers about engineering education. Table IV includes the main journals in the engineering education discipline. The data provided for each journal is: name, URL, first year of publication, number of articles published the last year (2008), number of issues per year, the involved associations, the impact factor and the ranking. These last two items have been taken from the research indexes published by Thomson Reuters: the Journal Citation Reports (JCR) Science Citation Index (SCI) and Social Science Citation Index (SSCI).

In the SCI and SSCI the research relevance of a journal is given by its impact factor. Nevertheless, the impact factor is usually not taken into account as an absolute number, but in the context of the category in which the journal is included. In this way, these indexes arrange journals in several categories and the relevance of each journal is considered in accordance with its relative impact factor position regarding all the journals in the same category. Usually, the categories are arranged in four quartiles and the journals in the firsts quartiles are the more important ones. As the reader can see, some journals are included in several categories and in this case it is usually taken the more favorable classification.

1) Journals in the JCR Science Edition

There exist several journals related with engineering education in 6 areas. The aims and purposes of the main journals are the following ones:

- *Computers and Education*. It is a technically-based, interdisciplinary forum for communication in the use of all forms of computing in the use of computing and Communications technology to contribute to all aspects of cognition, education and training, from primary to tertiary and in growing open and distance learning environments.
- *IEEE Transactions on Education*. The scope of this journal covers "educational methods, educational technology, instructional materials, history of science and technology, and educational and professional development, as well as programs within electrical engineering, computer engineering, and allied disciplines".
- *Journal of Engineering Education* focuses exclusively on scholarly educational research in engineering education.
- *Science and Engineering Ethics*. This journal explores ethical issues confronting scientists and engineers. "*Coverage encompasses professional education, standards and ethics in research and practice, extending to the effects of innovation on society at large*".
- *International Journal of Engineering Education.* This is an interdisciplinary journal, which tries to provide a balance between papers on developments in educational methods technology, case studies, laboratory applications, new theoretical approaches, educational policy and survey papers.
- *IEEE Technology and Society Magazine* covers a vast area of topics, including engineering ethics and professional responsibility, engineering education and technical expertise.
- *International Journal of Technology and Design Education "encourages research and scholarly writing covering all aspects of technology and design education. The journal features critical, review, and comparative studies. In addition, it includes contributions that draw upon other fields such as historical, philosophical, sociological, or psychological studies that address issues of concern to technology and design education*".
- *Computer Applications in Engineering Education* focuses "*on the innovative uses of computers and software tools in education and for accelerating the integration of computers into the engineering curriculum*".
- *International Journal of Electrical Engineering Education* "*features articles and book reviews which highlight aspects of the teaching of current topics in electrical and electronic engineering. Within an engineering educational context, these can range from specific projects, case studies and reports of laboratory practice to broader developments such as new teaching methods, curriculum design, assessment, validation and the impact of new Technologies*".

TABLE IV. MAIN ENGINEERING EDUCATION JOURNALS

Name	*URL*	*First Year*	*Articles in 2008*	*Issues / year*	*Involved Associations*	*Impact Factor [a]*	*Journal Ranking [b]*
Computers and Education	www.elsevier.com/wps/find/journaldescription.cws_home/347/description#description	1976	230	8	-	2,190 (SCI)	17/94 [1]:Q1
IEEE Transactions on Education	ieeexplore.ieee.org/xpl/RecentIssue.jsp?puNumber=13	1963	61	4	IEEE ES	1,400 (SCI)	7/24 [2]:Q2 83/229 [3]:Q2
Journal of Engineering Education	www.asee.org/publications/jee	1993	-	4	ASEE, IGIP	1,093 (SCI)	11/24 [2]:Q2 22/67 [4]:Q2
Science and Engineering Ethics	www.opragen.co.uk	1995	35	4	-	0,563 (SCI)	41/67 [4]:Q3 14/41 [5]:Q2 25/42 [6]:Q3
International Journal of Engineering Education	www.ijee.dit.ie	1985	124	6	-	0,552 (SCI)	17/24 [2]:Q3 42/67 [4]:Q3
IEEE Technology and Society Magazine	ieeessit.org/technology_and_society	1990	21	4	IEEE SSIT[c]	0,450 (SCI)	176/229 [3]:Q4
International Journal of Technology and Design Education	www.springer.com/education/journal/10798	1990	3	22	-	0,429 (SCI)	19/24 [2]:Q4 50/67 [4]:Q4
Computer Applications in Engineering Education	www3.interscience.wiley.com/journal/38664/home	1996	37	4	-.	0,388 (SCI)	89/94 [1]:Q4 21/24 [2]:Q4 53/67 [4]:Q4
International Journal of Electrical Engineering Education	www.ingentaconnect.com/content/manup/ijeee	1963	28	4	-	0,118 (SCI)	24/24 [2]:Q4 211/229 [3]:Q4
Journal of Educational Technology & Society	www.ifets.info	1998	84	4	IEEE CS IEEE LT	0,982 (SSCI)	42/113 [7]/Q2

a. Thomson Scientific 2008 Journal Citations Report (JCR). SCI: Science Citation Index. SSCI: Social Science Citation Index

b. Position in the subject category and quartile of the JCR. Subject categories: [1] Computer Science, Interdisciplinary Applications; [2] Education, Scientific Disciplines; [3] Engineering, Electrical & Electronic; [4] Engineering, Multidisciplinary; [5] History & Philosophy of Science; [6] Multidisciplinary Sciences; [7] Education & Educational Research

c. *IEEE Society on Social Implications of Technology* (www.ieeessit.org)

2) Journals in the Social Science Citation Index

In addition to the JCR SCI there are other publications in the JCR SSCI. One of the more important is the Journal of Educational Technology & Society. This journal "*seeks academic articles on the issues affecting the developers of educational systems and educators who implement and manage such systems". The articles should discuss the perspectives of educators and (educational system) developers' communities and their relation to each other*".

Among the areas of the SSCI there is one named Education and Educational Research. This area includes 113 journals. It is important to notice that some journals are listed both in the SCI and in the SSCI, for example the *Journal of Engineering Education* and *Computers and Education*. Not all the journals in this category accept papers about engineering education, but some of them have as scope evaluation methods, case studies, innovative pedagogical methods, curriculum organization, etc.

3) Other Journals

There are several journals not indexed in the JCR but it is quite feasible that they will be indexed in the near future. These journals have not been included in the JCR because they have been initiated in recent years (it is needed some years to enable the calculation of the impact factor) or because they are just published on-line (up to date, just paper journals are considered in this index). Anyway, the following journals are very interesting and they use to include valuable articles:

- *ACM Transactions on Computing Education* (toce.acm.org). This journal was named as *Journal on Educational Resources in Computing* (JERIC) until January 2009. Endorsed among other ACM groups by the SIGCSE, it is intended to support all aspects of computing education. The intention of its editors and directors is "*that TOCE become the most prestigious and influential publication in computing education*".
- *Engineering Education: Journal of the Higher Education Academic Engineering Subject Centre* (www.engsc.ac.uk/journal/index.php/ee/about/editorial Policies#focusAndScope). Published twice a year since 2006 including two types of articles: (i) papers on any topic relevant to engineering education as pedagogic research papers, case studies, critical reviews and evaluations; and (ii) comments with scholarly responses to previously published articles from the journal.
- *European Journal of Engineering Education* (www.tandf.co.uk/journals/tf/03043797.html). It is published six times a year since January 2006 by the SEFI to provide a forum for dialogue between researchers and specialists in the field of engineering education mainly at European levels.
- *IEEE Multidisciplinary Engineering Education Magazine* (www.ewh.ieee.org/soc/e/sac/meem/index.php/meem). It is the official publication of the IEEE ES Student Activities Committee since 2005. This journal is run for and by students. It focuses on "*education, bearing in mind that the expected readers are the students/teachers/facilitators who will be responsible for designing educational programs*".
- *IEEE Transactions on Learning Technologies* (www.computer.org/portal/web/tlt). It is a joint publication of the IEEE CS and IEEE ES initiated in 2008 and with 4 numbers per year. This journal covers research on such topics as: innovative online learning systems, intelligent tutors, educational software applications and games, and simulation systems for education and training.
- *Inroads – SIGCSE Bulletin* (jinfo.lub.lu.se/jinfo?func=fullRecord&jId=14692&issn=10963936). Published since 1969 twice a year by the ACM SIGCSE it provides "*a forum for university educators to discuss concerns about development, implementation, and evaluation of computer science programs and courses, as well as syllabi and problem sets*".
- *International Journal of Artificial Intelligence in Education* (ihelp.usask.ca/iaied/ijaied/). This is the official journal of the AIED Society. It was initiated in 1989 and publishes 4 numbers per year with papers and other items (e.g. workshop proceedings, conference reports, invited powerpoint presentations, news items, etc.) concerned with the application of artificial intelligence techniques and concepts to the design of systems to support learning.
- *International Journal of Computer-Supported Collaborative Learning* (ijcscl.org). Its publication was initiated in 2006 by the ISLS to promote a deeper understanding of the nature, theory and practice of the uses of computer-supported collaborative learning. A main focus is how people learning in the context of collaborative activity and how to design the technological settings for collaboration.
- *Learning Technology Newsletter* (www.ieeetclt.org/content/newsletter). It is published 4 times per year since 1999 to report the activities of the IEEE LT.

IV. ENGINEERING EDUCATION IN SPAIN

Similarly to the worldwide level, engineering education in Spain has been developed as a proper discipline. This can be supported by the existence of several associations, conferences and journals. Next sections provide an outlook to the more important ones.

A. Associations

During the last years the CESEI has been a main actor in the promotion of engineering education as a main practice and research disciplines. A main proof of its activities has been the organization of awards to the best final studies project and PhD thesis during the last four years [6].

In addition to the Spanish chapter of the IEEE Education Society, there exist the following associations related with the engineering education:

- ADIE: *Asociación para el Desarrollo de la Informática Educativa* (www.adie.es/webadie/).
- AENUI: *Asociación de Enseñantes Universitarios de la Informática*.
- GEIDI: *Grupo de Estudio e Innovaciones Docentes de la Informática*.
- *Ibero-american association of institutes of engineering education.*
- Spain SIGCSE Chapter (www.sigcse.es).

B. Conferences

The following conferences accept contributions about engineering education:

- *Jornadas de Enseñanza Universitaria de la Informática* organized by the AENUI.
- CITA: *Congreso Iberoamericano de Telemática.*
- CUIEET: *Congreso Universitario de Innovación Educativa en las Enseñanzas Técnicas.*
- SIIE: *International Symposium on Computers in Education*.
- FINTDI: *Fomento e Innovación con Nuevas Tecnologías en la Docencia de la Ingeniería.*
- TAEE: *Tecnologías Aplicadas a la Enseñanza de la Electrónica*.

C. Journals

There are several journals in Spain or in the Latin-America area that publish papers about engineering education:

- IEEE RITA: *Revista Iberoamericana de Tecnologías del Aprendizaje* (webs.uvigo.es/cesei/RITA).
- *Novática* (www.ati.es/novatica) is not focused on education, but it publishes papers on this topic.
- *Revista de Educación* (www.revistaeducacion.mec.es) from the *Instituto Nacional de Evaluación y Calidad del Sistema Educativo*.
- *ReVisión* (ww.aenui.net/ReVision) published by the AENUI.
- CIEET: Cuadernos de Innovación Educativa en las Enseñanzas Técnicas published by the Board of Directors of Schools of Technical Engineering
- RIE: *Revista de Investigación Educativa* (www.um.es/depmide/RIE).
- RIED: *Revista Iberoamericana de Educación a Distancia* (www.utpl.edu.ec/ried).

V. Conclusion

Engineering education has flourished as a great discipline during the last years. In this way, there are a large number of associations involved organizing conferences and publishing journals on several topics of this area. At this point, it is usually a problem to identify the key actors and sources of information. The Technical Committee of the CESEI is trying to support this discipline. Particularly, it tries to identify the main actors involved, their goals and main activities. This paper includes a compilation of some of this data. We hope it can be valuable for novice and common users that at some point need precise information about this domain.

In any case, this cannot be considered as a finished work and we will continue updating it. Similarly, any contribution or comment is welcomed.

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A PRACTICAL ELECTRONIC INSTRUMENTATION COURSE FOR ENGINEERING STUDENTS

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ABSTRACT

A course on Electronic Instrumentation has recently been developed at the Universidad Autonoma de Madrid (Spain), which specifically emphasizes practical aspects. The objective of the course is to link theoretical principles with practical issues of electronic instrumentation through the development of a final project. First, students take practical work in several different scenarios, which are the basis for the design of an engineering project aimed to solve an electronic instrumentation problem which is set by the students. Students are exposed to a set of multidisciplinary aspects, both theoretical and practical, providing them with the ability of integrating blocks in which they have practically worked into a full instrumentation project. The course provides not only enhanced academic training but also increased student motivation, as students are encouraged to propose their own projects.

Key-words: electronic instrumentation, practical approach, correlation theory-practice, student evaluation.

1. INTRODUCTION

One of the fundamentals of the technological progress in the field of electronic instrumentation is the need for practical training as an essential part of the learning activity. The process of engineering generally consist of the following sequential activities [1]: i) conceive, ii) experiment, iii) design, iv) build, v) test, and vi) improve. In most of these activities, practical aspects are crucial. It is therefore necessary an exposure to these aspects, in order to make electrical and electronic engineering graduates more employable and productive when they enter industry. However, although the resources present in a typical engineering laboratory usually cover isolated blocks of a whole project, it is desirable that the students develop the abilities to integrate blocks of a project in which they have practically worked. This interest is motivated by many aspects and manifests at many levels, from the technical structure of the final product to as an element of the development scheme. Unfortunately, resources present in an electronic instrumentation laboratory are not always enough to guarantee the acquisition of the abilities to accomplish such integration process, especially aimed at industry engineering work.

With these ideas in mind, a course on Electronic Instrumentation has been developed at the Universidad Autonoma de Madrid, which is a mandatory subject of the last course of the M.Sc. in Telecommunication Engineering. The goal of the course is not only to provide students with the theoretical principles, but also to link them with the practical aspects of electronic instrumentation. First, the students take practical work in the technical abilities of the electronic instrumentation course in several different scenarios, using the available hardware at the laboratory. The objective of yielding awareness about the whole project is achieved by means of simulated case studies, which are designed by the students, and which include the hardware used in the laboratory as a critical part.

In this paper we describe the particulars of this course, highlighting his objectives and contributions, and we will analyze whether the practical implementation proposed indicates a successful achievement of the proposed objectives. The course has been successfully developed and taught to 40 students from February to May 2009. Results presented in the paper illustrate the relationship about the scores obtained by the students in theoretical and practical work, and also presents experiments comparing the scores in each of the modules of the proposed practical methodology proposed. There are also included the results of the final student official opinion polls that are conducted at Universidad Autonoma de Madrid every academic year. Outcomes have been satisfactory, showing that students are satisfied with the course, and more motivated since they are allowed to take active role in the design and experimentation of an electronic instrumentation system.

This paper is organized as follows. In Section 2, we highlight the motivation, objectives and contributions of the proposed methodology. The organization of the course is described in Section 3, including details of the practical sessions and of the evaluation methodology. Results of the course implementation are included in Section 4, giving details of the marks obtained by the students and the results of the student opinion polls. Conclusions are finally given in Section 5.

2. MOTIVATION, OBJECTIVES AND CONTRIBUTIONS OF THE PROPOSED METHODOLOGY

Modern electronic instrumentation requires broad knowledge of a multidisciplinary approach [2]. It is therefore fundamental that the students face problems not only related to the implementation of electronic instrumentation systems, but also to the integration of such implemented modules among an industrial development chain. The objectives of the course are therefore adequate to this principles. After completing the course, the students should be able to do the following:

- Understand the principles of electronic instrumentation.
- Understand the main specification of a measuring system.
- Utilize a PC-based hardware that provides interaction with external signals, sensors and devices.
- Design simple measuring systems and micro-controller-based applications.
- Learn to integrate hardware instrumentation modules into a full instrumentation project.

The resources needed to accomplish the first four objectives can be provided by the typically available resources in a laboratory at the university, and at a reasonable cost. However, the last objective is costly, since it implies the availability of a full industrial system in which the modules developed at the laboratory should be integrated. This exceeds the budget that many universities dedicate to teaching laboratories.

The accomplishment of all the objectives described, including the last one, motivates the organization of practical work proposed in this paper, which constitutes the main contribution of the proposed methodology. The idea is to divide the practical working time (15 hours) into four different sessions. The first three sessions consider the implementation of several hardware modules which can be developed with the available equipment at the laboratory. The last session is a case study proposed by the students under determined guidelines, where an engineering project is proposed considering the hardware modules developed. This last session will not be finally implemented, since it consists of a full engineering problem, but their specification must be detailed and all the proposed blocks of the project have to be described with the required level of an engineering project. Figure 1 summarizes the proposed methodology.

With the proposed course, students not only supplement their academic training in electronics, but also gain experience in applying theoretical knowledge to the resolution of practical problems.

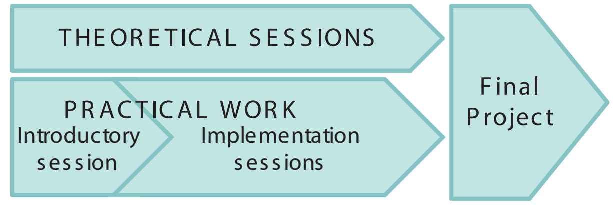

Fig. 1. Proposed practical methodology, which is the main contribution of the course.

Theoretical topics

1. General Principles of Instrumentation.
2. Statistical Error Analysis.
3. Electronic Instrumentation Amplifiers.
4. Analog-Digital Conversion.
5. Measurement of Physical Magnitudes.

Laboratory sessions

1. Introduction to Laboratory Hardware.
2. Thermometer Using the Analog-to-Digital Converter.
3. Dusk Indicator Using the Voltage Comparator.
4. Brushed DC Speed Control with Optical Encoder Feedback.
5. Engineering Project.

Table 1. Syllabus of our Electronic Instrumentation course.

3. ORGANIZATION OF THE COURSE

The organization of the course is summarized in the Syllabus presented in Table 1. The four-month course provides 4.5 lecture credits (45 hours in the current Spanish system) and 1.5 laboratory credits (15 hours in the current Spanish system). A set of laboratory sessions complement the theoretical training and a final design project is used to assess the practical knowledge acquired by students.

The required skills the students may have to take advantage of the course and achieve its objectives are as follows. It is recommended that students have passed previously other subjects on Circuits and Electronics, Circuit Analysis and Design, Signal Processing, Digital Systems and Programming (including assembly code). Therefore, it is intended for students with a previous background and skills in electronics.

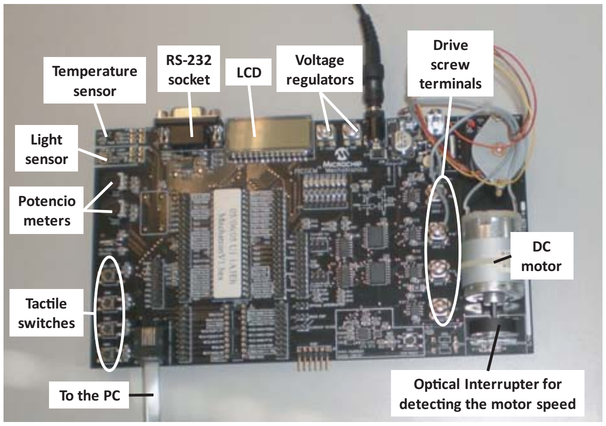

Fig. 2. Photograph of the PicDem development board from Microchip (TM) used in the laboratory practicals.

3.1. Theoretical Sessions

Theoretical sessions are mainly based on lectures which cover the topics included in Table 1 (top). These topics are typical in modern electronic instrumentation, and there is plenty of bibliography available. We have used mainly [3], which has proven to be an extremely useful resource for the course. Other useful references, recommended for the students were [4, 5].

3.2. Practical Sessions

Methodology

The practical methodology sketched in Figure 1 is developed as follows. The first introductory session and the subsequent three units in Table 1 are small projects where the students have to implement several functionalities using the available hardware of the lab.

The hardware used in the whole course is the so-called PicDem development board from Microchip (TM) (Figure 2), which is a platform to handle several electronic sensors (including a temperature, light and optical encoder sensor) and other devices (engines, light emitting diodes, etc.) using a PIC microcontroller. The software used to control the board is the MPLAB (TM) IDE [6], which runs on a Personal Computer (PC). Since it is running as software on the PC, it has complete information about the internal state of the microcontroller at each instruction (memory areas, register, peripherals, etc.), allowing real time monitoring.

The software includes several demonstration programs covering basic tasks such as reading a sensor, interfacing to a LCD and driving a motor. These projects also provide examples of how to use the various peripherals of the card. We have organized the laboratory sessions so that they are based on the use of these projects. The projects are of increasing difficulty, allowing to build knowledge as students progress from one project to the next. The assembly source code has comments with allow to identify relevant steps, so students are able to monitor the execution although they are not familiar with the specific programming language. This avoids tieing students to a manufacturer-dependent solution, which is quire important in such a changing technological field [2]. At the same time, students do not have to invest time on learning specificities of the particular micro-controller which, in all probability, will be different to those that they will find in their respective job positions.

Sessions Organization

The students are organized in teams of a maximum of 2 members, and they work together to accomplish the objectives in each of the laboratory sessions. Each session lasts 2 hours and the sessions are organized considering that the amount of work needed exceeds the 2 hours available, therefore a substantial amount of work should be performed by the student outside the session. The sessions and the main expected results are described as follows (see Table 1, bottom):

1. Introduction to Laboratory Hardware. The hardware used in the laboratory (PicDem board) and the PC-based interface (MPLAB (TM) IDE) is described, with the aim of serving as an interface for the students to start interacting the system.

2. Thermometer Using the Analog-to-Digital Converter. A thermometer is implemented using the temperature sensor in the PicDem. Then, the static transfer function of the thermometer is measured, taking different references of various reliability. The aim is to highlight the importance of a proper calibration process, as well as to let the students learning to work with analog-to-digital converters (ADC) and conditioning circuits. This covers several of the theoretical aspects of the course (theoretical topics 1, 4 and 5 in Table 1).

3. Dusk Indicator Using the Voltage Comparator. A dusk indicator is implemented using the light sensor of the PicDem. Using the PC-based interface, the charactersitics of the components are measured (sensor, comparator). The need of hysteresis in the whole process is analyzed and a hardware alternative for its implementation is theoretically derived. This session covers part of theoretical topics 1, 2 and 5 in Table 1.

4. Brushed DC Speed Control with Optical Encoder Feedback. A DC motor is controlled by the use of the optical encoder present in the PicDem board. The characteristics of the motor and the PicDem are measured and documented using the PC-based interface. Moreover, the circuit used to feed the motor (Pulse Width Modulation circuit included in the PIC of the board) is also characterized. Finally, the static transfer function

relating speed to input voltage is estimated under several situations, leading to a complete understanding of the system under analysis. This sesison covers part of theoretical topics 1, 2, 4 and 5 in Table 1.

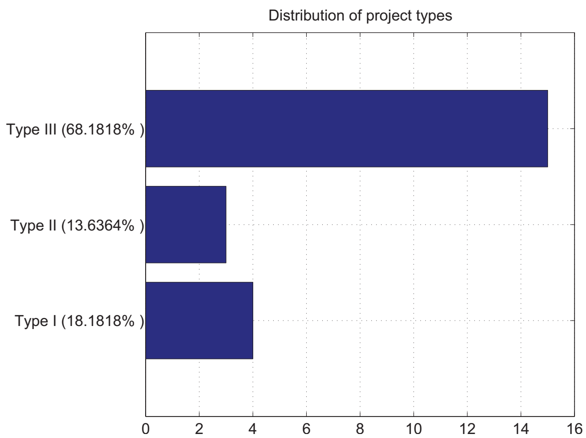

Fig. 3. Distribution of project types (I, II and III with increasing difficulty) among different teams of students for the laboratory session 5 of the proposed practical methodology.

Engineering Project

The main contribution of the proposed methodology is the existence of a final project (lab session 5 in Table 1) whose aim is to integrate part of the developed modules in previous sessions into a full engineering project. Thus, in this last session students are asked to design an engineering project to solve an electronic instrumentation problem which is set by themselves. The main condition of the project is the use of the laboratory hardware as a critical component. The proposed work methodology considers the following steps:

- **Identification of an engineering problem** where electronic instrumentation will play a fundamental role. For this section, the students must be creative in applying all the concepts acquired in the theoretical sessions, also considering the modules implemented in previous practical sessions. Aspects to evaluate are the potential difficulty and the originality of the problem.

- **Identification of the components** needed to solve the instrumentation problem in the form of an engineering project. In this section, not only the components have to be specified, but also their relationship with the available hardware, namely PicDem (Figure 2). The level of detail to be specified is maximum, with the requirement of finding technical sheets for each component, and also to explain it deeply in order to integrate it in the whole project. The components may be PicDem components (either used in previous sessions or not previously explored at all) or other external components. The evaluation of this step will be based on the difficulty to find the specified components, the technical adequacy of them to the problem, the performance with respect to other options in the market and the level of detail of their description (technical sheets and additional information).

- **Engineering project.** Here the student should give a solution to the proposed problem in the form of an engineering project. It is not a requirement to make the programming routines for PicDem operation in assembly code, but the pseudo-code of its operation should be included. Schematics, diagrams and detailed descriptions of the solution adopted with a clear explanation of the relationship among components and with the problem to solve are also required. In this section the evaluation will be based on the quality of the schematics and diagrams, the adequacy of the project to the problem to solve, the quality of the explanations and the implementability of the designs and solutions adopted.

Several types of possible projects are proposed to the students, which serve as guidelines to their development. Each type of project presents an increasing difficulty which allows students to quantify the relevance of the problem presented and the solution adopted. The proposed project types and their characteristics are specified here:

1. **Type I Project.** This project basically consists of improving one of the modules implemented in previous sessions in order to give solution to the problem proposed by the students. No internal or external component is required. This project is the easiest of all, which is considered in the evaluation (see Section 3.3).

2. **Type II Project.** This project considers two alternatives: i) the project includes other components of the PicDem not used in previous sessions; or ii) the project includes other components external to the PicDem. Given the difficulty of searching, analyzing and specifying components not seen before, the evaluation of this project is more favorable than in the Type I (but less than the Type III, see next).

3. **Type III Project.** In this project, both components of the PicDem not used in previous sessions and other components external to the PicDem are used. Given the difficulty of searching, analyzing and specifying components not seen before, the evaluation of this project is the most favorable of all the proposed Types.

3.3. Evaluation

As it happens in the Spanish education system, the evaluation of a course is given in a $[0, 10]$ interval, being 0 the minimum

Type I

- Measurement of Light Time.
- Motor Control by Temperature Sensor.
- Motor Control by Temperature Sensor.
- Motor Control by Temperature Sensor and Speed Measurement.

Type II

- Control of a Window Blind by Light Sensor.
- Domotic Control of a House.
- Motor Control by Temperature and Light sensors, and Switches.

Type III

- Automation of a Lighthouse.
- Control of a Canopy by Humidity and Light Sensors.
- Hold-on Time Control for a Bus Line.
- Measurement of Glucose Level.
- Motor Control by Strain Gauges.
- Obstacle Map Design.
- Simulation of Inhabited House.
- Smoke Detector.
- Stability Control of a Car.
- Temperature and Humidity Measurement and Registry.
- Temperature Controller.
- Temperature Measurement and Registry.
- Turbo-Engine Pressure Control by Solenoid Valve.

Table 2. Project titles grouped by project type.

score and 10 the maximum score, and considering that a student passes an exam when his/her score is greater or equal than 5. The evaluation of the whole Electronic Instrumentation course was given by the following formula, derived from the current rules at Escuela Politecnica Superior at Universidad Autonoma de Madrid:

$$FS = 0.25 \times PS + 0.75 \times TS \qquad (1)$$

where FS is the final score of the course, TS represents the score obtained in the evaluation of the theoretical work and PS is the score of the practical work. As additional constrains, it must happen that both $TS \geq 5$ and $PS \geq 5$, meaning that the student has to demonstrate his attitudes both for theoretical and practical work.

The theoretical score TS is obtained from an exam where the knowledge acquired in theoretical sessions is evaluated. The exam encompasses a closed-answer test (30% of TS) and some design problems to solve (70% of TS). For this exam, according to the Spanish law, a student can attend two times per year. If they do not pass the first call (in June) they can attend to the second call.

The criteria for evaluation of all the practical part of the course has been transparent in all moment, with the students being informed of it conveniently from the beginning. The score PS is computed as follows:

$$PS = 0.20 \times S_2 + 0.20 \times S_3 + 0.20 \times S_4 + 0.40 \times S_5 \qquad (2)$$

where S_i is the score obtained in laboratory session i as it is enumerated in Table 1 (bottom). It can be noticed that laboratory session 1 is not evaluated, because it is an introductory session. Moreover, the project represent almost half of TS, representing the emphasis that the practical methodology of the course presented in this paper puts in the integration of modules into a full engineering project.

For the evaluation of the engineering project (laboratory session 5 in Table 1) the project types (Type I, II and III, see Section 3.2) has an influence in the final qualification. The idea followed is that the more difficult the project, the more difficult will be to achieve a higher score. However, there is the opportunity of achieving the highest score with all the project types if the quality is sufficiently high. Thus, a correction factor has been imposed to the score obtained in laboratory session 5 depending of the project type that the students have selected. In this way, Type III projects would tend to obtain the highest scores, whereas Type 1 projects will tend to obtain the lowest scores.

4. RESULTS

The results presented here are interpreted over a sample of 40 students of the last course of Telecommunication Engineering at Universidad Autonoma de Madrid. Since the students are

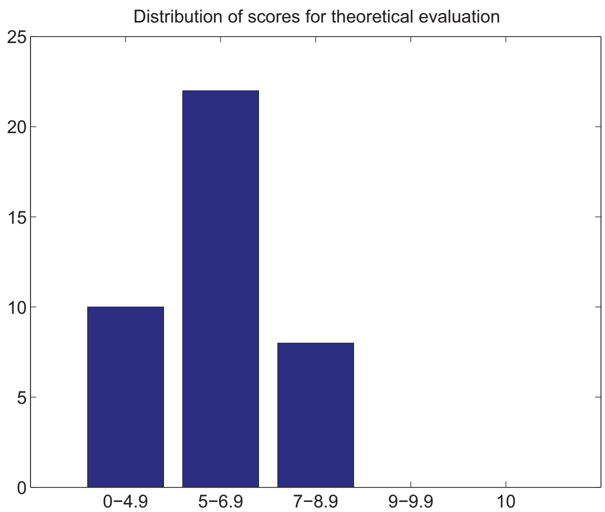

Fig. 4. Histogram of theoretical scores TS following the Spanish evaluation system (from 0 to 10). 40 students analyzed.

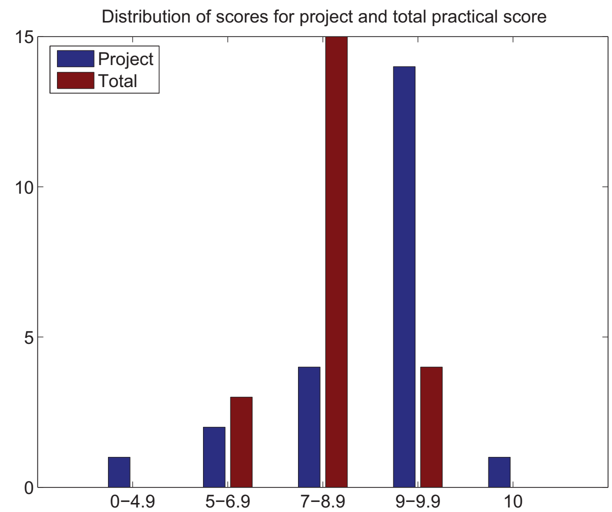

Fig. 5. Histogram of practical scores PS and scores for the proposed project S_5 following the Spanish evaluation system (from 0 to 10). 22 teams analyzed.

organized into teams of maximum 2 people for practical laboratory work, the sample reduces to 22 teams for the analysis of the outcomes from the practical part of the subject. Also, since 2009 was the first year in which the proposed methodology is implemented, the sample cannot be compared in time. This is proposed as future work of this contribution.

4.1. Project type distribution

Distribution of project types among teams in the selected sample is shown in Figure 3. It is shown that the students have mainly selected Type III projects, which are much more difficult to develop. This is an indication of the degree of motivation of the students with respect to the proposed methodology. Moreover, given the transparency in the evaluation methodology followed, such distribution means that the students are ready and willing to explore and deeply specify components not seen before, and to integrate it into an engineering process. This is an indicator that the knowledge acquired in the theoretical-practical methodology followed seems sufficient for them in order to accomplish the objectives of the project.

Table 2 lists all the titles of the projects, classified by project type. It is observed that the originality of the project title depends on the type of project, being Type I projects much more typically seen than Type III projects.

4.2. Scores

The scores obtained in the theoretical subject (TS scores) are represented in Figure 4. it is observed that the scores concentrate in the 5 to 8 region, not being higher than 9 in any case. This is an indicative that, although the vast majority of the students pass the exam ($TS \geq 5$), obtaining the maximum score (10) is extremely difficult. This has been the trend in Spanish evaluation methodologies over decades.

Figure 5 shows histograms with the distribution of the scores obtained in the practical part of the course, compared to the score obtained in the proposed project (laboratory session 5). It is observed that, in general, the scores in the practical part of the course are significantly higher than in the theoretical part of the course (compare with Figure 4). This was a design requirement, since the challenge of practical sessions should be kept while fostering the student's motivation. Moreover, in general it is observed that the trend of the scores in the proposed project is much higher than the total score. That means that, despite the intrinsic difficulty of an engineering project, the students have taken the initiative to accomplish it in a successful way. Figure 6 shows the distribution of scores for each of the sessions in the practical part of the course, namely S_2, S_3, S_4 and S_5. These results confirm this trend, showing a remarkable improvement in the score obtained by the students with the number of laboratory session.

Correlation between theoretical knowledge acquired and practical competencies is shown in Figure 7. It is observed that the correlation coefficient among the theoretical score (TS) and the practical score (PS) is positive, and having a non-negligible value of 0.32 from a maximum of one. That indicates that the theoretical knowledge gained by the students is in relation to the practical abilities achieved, which fulfills part of the objectives of the course. This is also seen in Figure 8. if we obtain the correlation between the theoretical score and the proposed project (laboratory session 5).

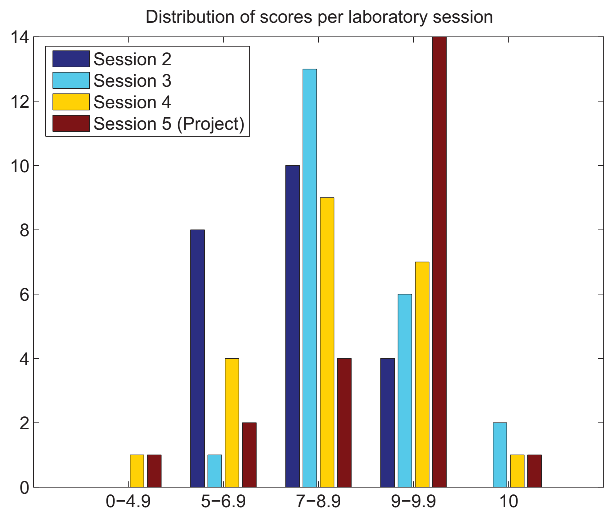

Fig. 6. Histogram of practical scores for all the laboratory sessions following the Spanish evaluation system (from 0 to 10). 22 teams analyzed.

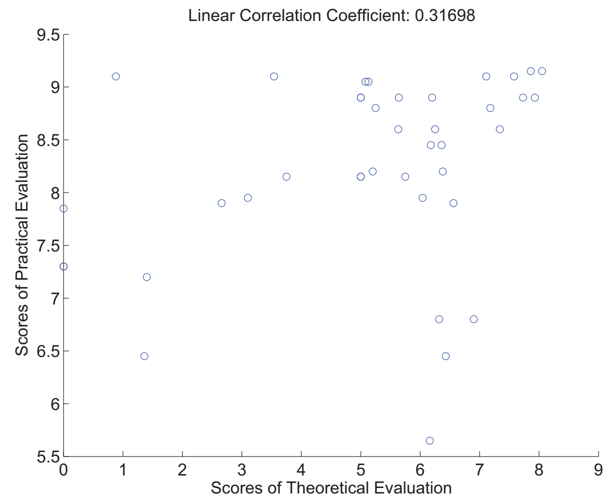

Fig. 7. Scatter plots showing correlation between theoretical scores (TS) and practical scores (PS). Correlation coefficient is also shown. 40 students analyzed.

Again, the correlation is positive, and the coefficient has also a non-negligible value, in this case of 0.25, indicating that the objective of the proposed project of yielding practical and theoretical abilities to students to solve electronic instrumentation problems has been achieved.

4.3. Official student opinion polls

Figure 9 shows the results of the official polls conducted by Universidad Autonoma de Madrid, illustrating the opinion of the students about their work in the laboratory. The aspects evaluated are the following:

1. Clarity of concepts.
2. Organization.
3. The teacher dominates the subject.
4. Availability of the teacher in case of doubt.
5. Receptive and friendly attitude of the teacher.
6. Regularity of assistance.
7. Punctuality.
8. **General opinion about the laboratory.**

The results of such polls are extremely satisfactory, over the mean value of the same school and university. That indicates that, although such results do not refer strictly to technical topics, the laboratory has been worthy for the students, and their degree of satisfaction is excellent.

5. CONCLUSIONS

The design of modern electronic instrumentation requires broad knowledge and a multidisciplinary approach, as reflected in the structure of this course. A final design project is used to link theoretical principles with practical issues of electronic instrumentation, so that they acquire the ability of integrating blocks in which they have practically worked into a full instrumentation project.

Outcomes have been extremely satisfactory. Students enhance their academic education, are more motivated, play an active role in project design and receive crucial pre-career exposure to practical aspects. Among the different types of possible projects, students go for the more difficult to develop, which is an indication of the degree of motivation of the students with the proposed methodology. Distribution of marks show an increasing tendency with the number of laboratory session, indicating a correct progress of the students throughout the course. Finally, results of the opinion polls carried out at the University show an excellent degree of satisfaction by the students.

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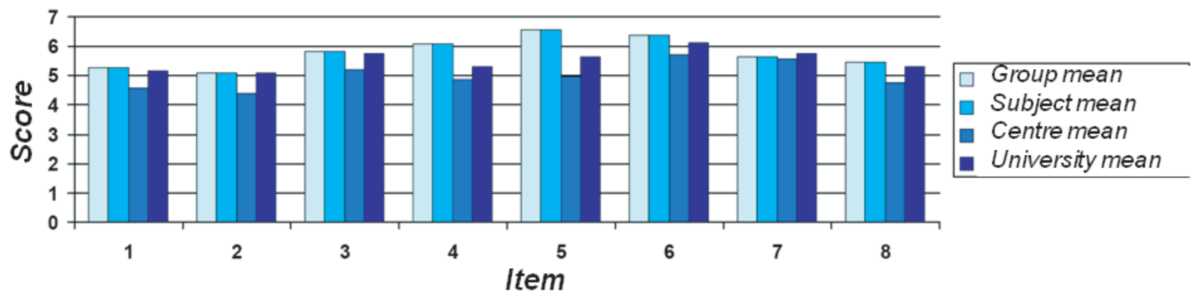

Fig. 9. Results of the official student opinion polls for the practical part of the course.

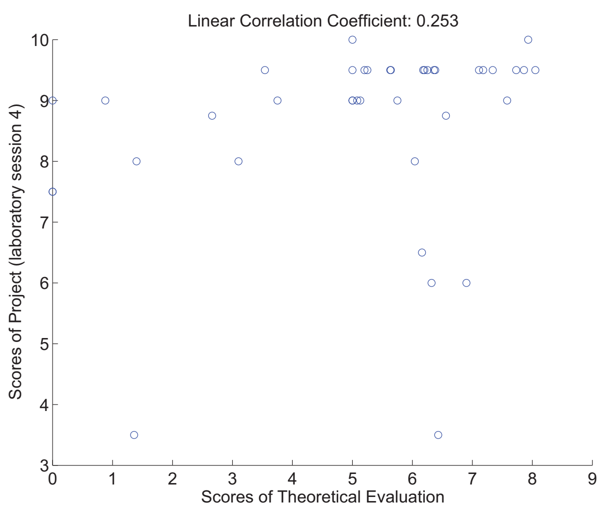

Fig. 8. Scatter plots showing correlation between theoretical scores (TS) and scores for the proposed project (S_5). Correlation coefficient is also shown. 40 students analyzed.

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Teaching Microprocessors Design Using FPGAs

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Abstract— **Microprocessors is a typical subject within the Computer Architecture field of scope. It is quite common to use simulators in practical sessions, due to the complexity of its contents. In this paper a new methodology based on practical sessions with real devices and chips is proposed. Simple designs of microprocessors are exposed to the students at the beginning, rising the complexity gradually toward a final design with a multiprocessor integrated in a single FPGA chip. Finally, assessment results are shown.**

Keywords: Learning Experiences; Laboratory Experiences; Teaching Engineering; Computer Architecture

I. INTRODUCTION

Traditional laboratory practical sessions to teach microprocessors are based on simulators, in this paper an experience implementing real microprocessors is shown. The main purpose is to encourage the student interest and to improve the assessment. This proposal is useful for many subjects within several engineering degrees. This activity was carried out in particular in the Microprocessors subject, in the degree in Computer Sciences at the University of Córdoba.

In most cases, computer architecture has been taught with software simulators [1], [2]. These simulators are useful to show: internal values in registers, memory accesses, cache fails, etc. However, the structure of the microprocessor is not visible, and students are not aware learning a real processor. Recently [3], [4], digital design is being teaching using real Programmable Logic Devices (PLD), showing it attractiveness for the students. Also recent works shown how the learning throw projects and games based on FPGAs are very useful [5].

In this work, a methodology for easy design and real implementation of microprocessors is proposed, in order to provide students with a user-friendly tool. Simple designs of microprocessors are exposed to the students at the beginning, rising the complexity gradually toward a final design with two processors integrated in an FPGA; each of which has an independent memory system, and are intercommunicated with a unidirectional serial channel. Furthermore, an introduction to the architecture of a T1 SUN OpenSparc system with 8 processors, 4 thread/processor plus one MicroBlaze is introduced at the end of the semester while students are working on their projects, this final seminar is useful because students are encouraged when see that a high performance parallel architecture is suitable of being implemented on a single FPGA Virtex5 [6].

In this paper the methodology to design and implement a microprocessor or multiprocesors is presented. To illustrate it with high detail and in a useful way, how to design the most complex practical session is shown. In section I, other methodologies based on simulators are referenced. The software platform used to implement real processors is presented in section II. Features of MicroBlaze processor are introduced in section III. The course practical content is described in section IV. To illustrate how a processor is designed and implemented, section V presents a brief guide of how to build a biprocessor, this is the most complex practical session. Finally, conclusions are presented in section VI.

II. SOFTWARE TOOL

The Xilinx Platform Studio (XPS) is used to design MicroBlaze processors. XPS is a graphical IDE for developing and debugging hardware and software. XPS simplifies the procedure to the users, allowing them to select, interconnect, and configure components of the final system. Dealing with this activity, the student learns to add processors and peripherals, to connect them through buses, to determine the processor memory extension and allocation, to define and connect internal and external ports, and to customize the configuration parameters of the components. Once the hardware platform is built, the students learn many concepts about the software layer, such as: assigning drivers to peripherals, including libraries, selecting the operative system (OS), defining processor and drivers parameters, assigning interruption drivers, establishing OS and libraries parameters.

Students have deeper documentation available in [7], [8], and other useful resources recommended are [9], and, [10].

An embedded system performed with XPS can be summarized as a conjunction of a Hardware Platform (HWP) and a Software Platform (SWP), each defined separately.

A. The Hardware Platform

The HWP is described in the Microprocessor Hardware Specification (MHS) file; it contains the description of the system architecture, the memory map and the configuration parameters. HWP can be defined as one or more processors connected to one or more peripherals through one or more buses. The definition of the activity follows this sequence:

- To add processors and peripherals.
- To connect them through buses.

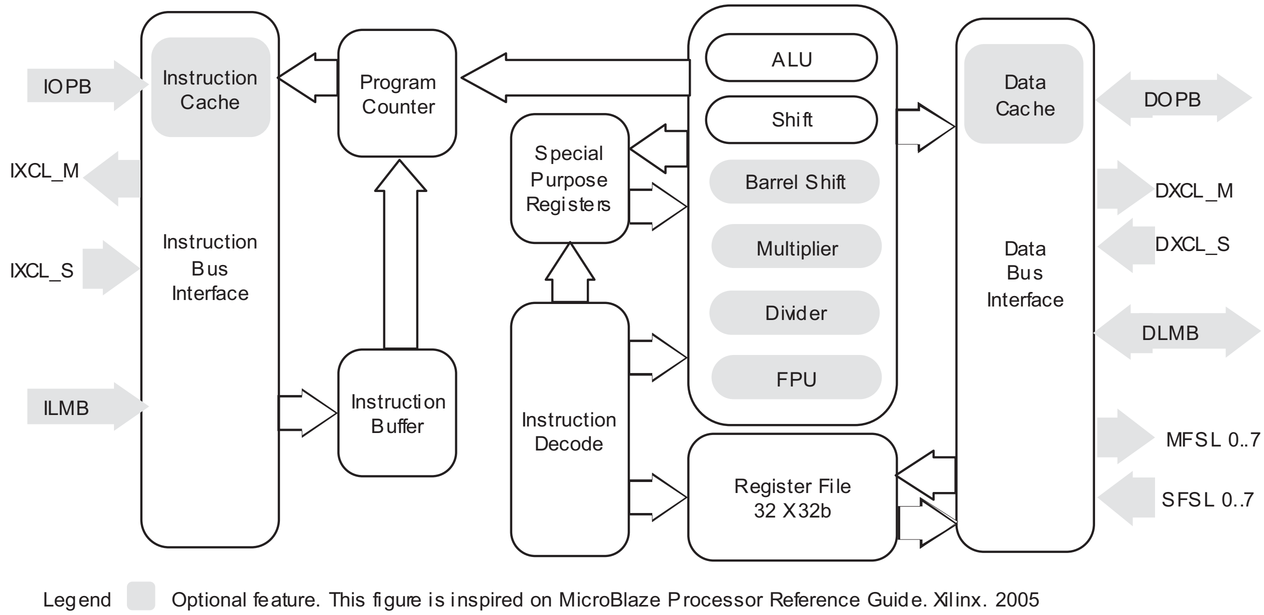

Figure 1. MicroBlaze architecture. In gray, reconfigurable components

- To determine the processor memory allocation.
- To define and connect internal and external ports.
- To customize the configuration parameters of the components.

B. The Software Platform

The SWP is described in the Microprocessor Software Specification (MSS) file; it contains the description of drivers, component libraries, configuration parameters, standard input/output devices, interruption routines and other software features. The sequence of activities needed to define the SWP is the following:

- To assign drivers to peripherals.
- To assign interruption drivers.
- To establish OS and libraries' parameters.

III. The MicroBlaze Processor

MicroBlaze is a 32-bit specific purpose processor developed by Xilinx in VHDL. It can be parameterized using XPS to obtain an *à-la-carte* processor. It is a RISC processor, structured as a Harvard architecture with separated data and instruction interfaces.

MicroBlaze components are divided into two main groups depending on their configurability as shown in Fig.1.

Some fixed feature components are:

- 32 general purpose registers sized 32-bit each.
- Instructions with 32 bits word-sized, with 3 operands and 2 addressing modes.
- 32 bits address bus.
- 3-stage Pipeline.

Some of the most important configurable options are:

- An interface with OPB (On-chip Peripheral Bus) data bus.
- An interface with OPB instruction bus.
- An interface with LMB (Local Memory Bus) data bus.
- An interface with LMB instruction bus.
- Instruction cache.
- To include EDK libraries.
- To select the operative system (OS).
- To define processor and drivers' parameters.
- Data cache.
- 8 Fast Simplex Link (FSL bus) Interfaces.
- CacheLink bus support.
- Hardware exception support.
- Floating Point Unit (FPU).

IV. Practical Designs

Practical sessions introduce gradual learning, allowing the fast design based on previous sessions. Essential problems in hardware programming will be raised:

- Hyperterminal serial communication.
- Using IO ports.
- Memory controller.
- Interruption routines and priority.

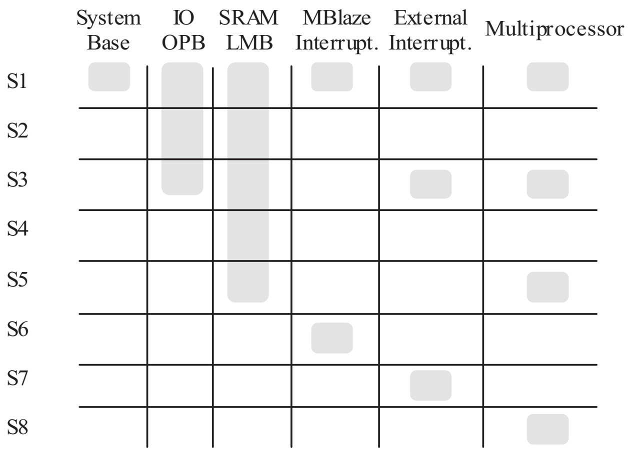

Figure 2. Sessions and contents.

- Message passing in multiprocessors communication.

The practical content of the subject is composed of 8 projects. In the first session, students make a basic system which will be used in following sessions as the base core system. Second and third sessions are used to introduce the input/output flow and the communication with external peripheral through the On-chip Peripheral Bus, for general purpose. SRAM external memory is added to the system at fourth session. Next session is dedicated to the External Memory Controller and how to split the bus. MicroBlaze interruptions are added in the sixth session, and external interruptions using the interruption controller are included in the seventh session. Finally, students build a biprocessor, using the Fast Simple Link channel at session eight. In fig. 2 the relation between practices is shown. For instance, 5th session is based on all previous sessions, 7th session is based on 3rd and 1st session.

V. Biprocessor System Design

The last and most complex practical session is the design and implementation of a biprocessor. A computational system composed of two MicroBlazes will be designed. Both MicroBlazes will be interconnected using message-passing protocol. Each MicroBlaze has its own non-shared memory for instructions and data.

In the Fig. 3 a diagram with the structure of the design is shown. In it, the buses and components used have been detailed. It also includes how they are interconnected

At first, following the logical sequence exposed previously, a HWP will be created. This HWP will include the configuration of the components and buses, their interconnection, the memory map, ports and other parameters.

In the following subsection, the steps needed to configure the system will be described. Trivial stages, such as the creation of the project, will not be included in this paper. The parameters shown in this section depends on the FPGA chip, in this case the Spartan 3 board [11].

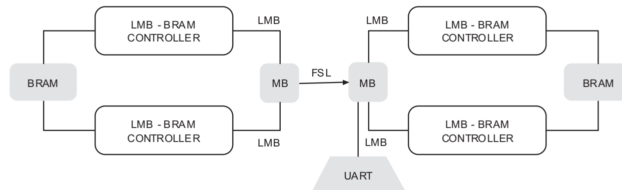

Figure 3. Biprocessor system diagram.

A. Hardware Platform Specifications

This stage is described in the MHS file. Following, the components specified in the structure of the system are enumerated:

- Two MicroBlaze processors.
- Two on-chip RAM memory blocks (BRAM), one for each processor.
- One UART.
- One OPB bus, to connect the UART with the slave processor.
- Two LMB buses to communicate each processor with their respective data memory controller; and another two LMB buses to interconnect the processors with their instruction memory controller.
- One FSL channel to intercommunicate each processor with the other.

After that, the interconnection of buses and components is defined. The connection of the memory ports are also set at this point. The student has to specify in the connection matrix which components are linked to which buses and with which kind of connection.

In the exposed case, four LMB buses are needed to access local memory, two for each MicroBlaze, because each processor has its own memory subsystem.

Also, one FSL channel which connects both processors.

Each BRAM has been designed with 4 different ports. Each MicroBlaze reaches its memory block through two different interfaces (instructions and data).

After that, it is necessary to map the components inside the configuration memory of the processors. XPS provides a functionality which is able to compute automatically a valid configuration memory map for a monoprocessor system structure. However, as the system proposed is a biprocessor one, this functionality cannot be used.

Each MicroBlaze looks for the first instruction in its program at memory address 0x0.

The next step is to define the internal and external ports. Most of the internal ones are configured by XPS with default settings. It is also necessary to define and to connect some of the internal ports to make the system works: those ports related to the reset and clock signals must be forwarded to all of the subsystems and components. Four external ports are mandatory: clock, reset, UART in and UART out. With these ports, the student sends commands and synchronization information to the system. Finally, the components are configured. The parameters for each component and their meaning are described thoroughly in the documentation included in the XPS platform.

Particularly, MicroBlaze includes a parameter which selects the amount of FSL interfaces used. Thus, both processors have to set this configuration value to one to allow the communication between them. The configuration of this parameter is done by changing C_FSL_LINKS. This parameter has to be set to a numerical value, representing the amount of FSL interfaces to be included in the core.

Another interesting configuration to be mentioned is the UART operational configuration. The student has to determine the operational frequency, the application of the parity bit checking, working bauds, etc. A valid set of parameters for the UART and MicroBlaze are the following:

1) *UART parameters.*

a) C_CLK_FREQ = 50_000_000. Set the frequency of the OPB bus, connected to the UART. It has to coincide with the operational system speed.

b) C_BAUDRATE = 19200. Set the bauds for the UART. The terminal used to receive characters has to be configured at the same baud rate.

c) C_USE_PARITY = 0. Set whether the UART should work with parity bit or not.

2) *MicroBlaze parameters.*

a) C_FSL_LINKS = 1. In order to communicate between the two processors, at least, one FSL channel has to be defined.

After the HWP is defined, the netlist files and the support files can be generated.

B. Constraints File

The constraints file specifies how external ports from the designed system correspond with the Spartan-3 Board [ ] pins:

```
# Clock signal.
Net sys_clk LOC=T9;
Net sys_clk TNM_NET = sys_clk;
TIMESPEC TS_sys_clk = PERIOD
sys_clk 20000 ps;
# Reset button
Net sys_reset LOC=l14;
Net sys_reset TIG;
# UART
NET TX LOC = R13;
NET RX LOC = T13;
```

Once the constraint file and the HWP are ready, XPS has enough information to create the internal bitstream file.

C. Software Platform Specification

The SWP corresponds with the Microprocessor Software Specification (MSS). The first step is to select the drivers for the components, the SWP libraries and the OS for each processor. In this project, the standalone OS is selected, no libraries are used and the drivers for the components are established by default.

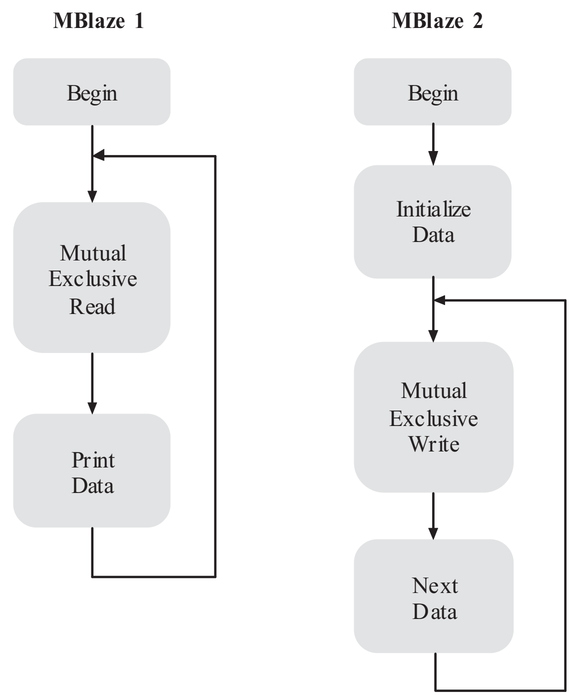

Figure 4. Software application flowchart.

In the following step, the configurable parameters from processors and drivers must be edited; also the interruption routines must be assigned if needed; for instance, in the system under explanation, the interruption routines are not used. In this case, all fields are configured by default except for the processors, which must be configured to work at 100 MHz.

In the final step, the OS libraries configuration parameters are edited and configured. The standalone OS has a minimum size software layer with some primitives for input/output, control, memory allocation, etc.

In the proposed system, the student must specify the UART as the input/output standard peripheral. This is established by assigning the UART to the OPB master MicroBlaze.

Once SWP is configured, it is possible to program the processors software code. However, it is necessary to generate previously the libraries and the Board Support Package (BSP).

D. Software Application

To carry out the goals of this work it is necessary to create two SW projects, one for each MicroBlaze. With these, each Microblaze will execute its own program.

Some primitives are used to allow a fluid message passing between both processors through the FSL channel.

The writer processor generates the data that will be sent to the reader processor through the FSL channel using mutual exclusion primitives for message passing. The OPB bus master sends the data received by the reader processor to the UART.

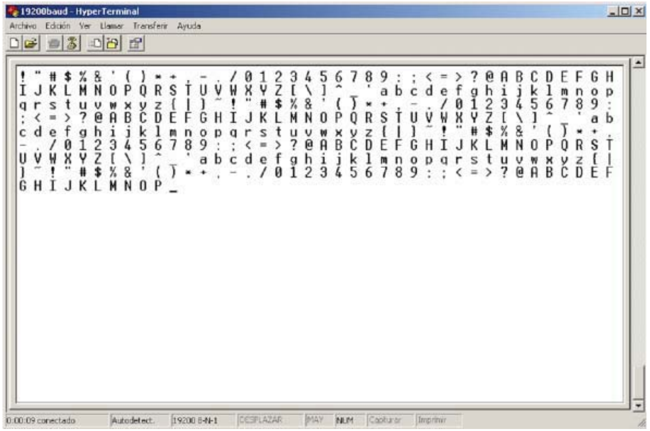

Figure 5. Hyperterminal capture while the both processors are i

After the compilation of the software application, the FPGA configuration file is generated.

Finally, the configuration file is loaded into the FPGA. After all these steps, the students execute the global system and they verify that both processors work properly: The reader processor reads data generated from the writer processor, and the writer processor generates successive data. This process is shown in Fig. 4.

Following the code based on C language for both MicroBlaze processors is shown. Some Xilinx libraries are required to optimize the code and to use some resources:

MicroBlaze 1 Code. Reading data from MicroBlaze 2 and showing them in the UART

```
#include <mb_interface.h>
int main( )
{
  int i;
  while(1) {
    microblaze_bread_datafsl(i,0);
    xil_printf("%c ",i); }
  return;
}
```

MicroBlaze 2 Code. Generating consecutive ascii characters and sending them to MicroBlaze 1 through FSL

```
#include <mb_interface.h>
int main()
{
  int i = 33;
  int c;
  while(1) {
    for(c=0;c<10000000;c++);
    for(c=0;c<10000000;c++);
    icroblaze_bwrite_datafsl(i,0);
    i++;
    if(i>126) i=33; }
  return;
}
```

Hyperterminal screen was captured and is shown in Fig. 5 to show the results when the both processors are running.

VI. Conclusions

XPS can be used as an excellent tool for the students to design and build complex architectures avoiding implementation details. Otherwise, they would spend a lot of time until they master concepts and techniques to develop those systems. Students understand the functionality and the structure of the different components, in order to interconnect all of them to build either a monoprocessor or a biprocessor.

A notable improvement of the qualifications compared to the average of the previous five years was obtained. In particular, in 2008 an improvement of 21% was obtained in front of the mean of the assessment for 2005-07 period. In 2009 the improvement in the assessment was 22%.

As a result of a survey, students are more motivated using real devices than using just simulators.

Furthermore, the configuration of each of the component parameters contributes to a better understanding of the developed architecture. And they are able to test how different values for those parameters influence the performance of the whole system. Finally, a guide on how to implement several processors systems on a single FPGA chip has been provided.

Acknowledgment

Authors wish to remark the great task carried out by the Xilinx University Program, XUP; and the Sun Microsystems OpenSPARC University Program, which have donated software and materials which have been very useful to partially finance this work.

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Development of a Small Radio Telescope at the Technical University of Cartagena

A duty with our students and society

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Abstract—**An initiative carried out at the Technical University of Cartagena (UPCT, Spain) to encourage students and promote the interest for Scientific and Engineering Culture between society is presented in this contribution. For this purpose, a medium-term (4 years) project based on the design, fabrication, testing and set-up of a small Radio Telescope system has been carried out. The main novelty is that this project is entirely being done by students of last courses of our Telecommunication Engineering Faculty, under the supervision of four lecturers.**

Keywords- Electrical engineering education; Electromagnetic engineering education; Systems engineering education.

I. INTRODUCTION

As we are immersed in the "Bologna process" to reach the EEES (European Space for Higher Education) [1], academic and government regulators request for innovate experiences to improve the learning process, highlighting the necessity of development of more practical, less theoretical, teamwork, interdisciplinary competencies. Very worrying is the reality detected in the last decade that shows that young people around Europe are losing their interest in Science and Engineering culture (see, for instance the objectives and effort made in Spain by FECYT [2]). Being aware of these facts and feeling responsible as part of a public University, some lecturers of the Telecommunication Engineering Faculty at the Technical University of Cartagena (UPCT) decided to undergo the experience of involving our last course students in the development of a Small Radio Telescope (SRT).

These lecturers coordinate some telecommunications related syllabus like Electromagnetism [3,4], Antenna Engineering [5,6] Microwave Engineering [7-8], or Radio Communication Systems [10]. We thought that Radio Astronomy [11-14], and particularly Amateur Radio Astronomy [15-17] is an interesting application of Microwave Engineering that might motivate students to put effort in these courses [18]. Moreover we though that involving the students in the setting-up, operation, maintenance and enhancement of a SRT system (see Figs.1-2) could be a good idea to have a permanent practical laboratory where they could feel free to improve their knowledge and skills related with these technologies. Besides, this Radio Telescope can serve as tool to attract future students to our Faculty, and also very useful to disseminate Radio Astronomy between non-specialized individuals, local amateur astronomers [19,20], and society in general.

Figure 1. Students and lecturers at work mounting the SRT antenna

The main novelty of this activity is that the entire Radio Telescope system (see scheme in Fig.2) is being entirely developed, manufactured, tested and set-up by the students, using the facilities available in our modest laboratories. To our knowledge, this is the first proposal in Spain to promote Radio Astronomy with these particular characteristics. Other public Spanish Universities proposals, such as the ones from the University of Valencia [21] or the University of Cantabria [22] have also made use of a SRT to introduce their students of Physics and Astronomy to this fascinating world. However, in these cases, the entire SRT was designed, manufactured and sold by external Engineering companies [23-26]. Another well-known example is the Spanish-NASA project known as PARTNeR [27] started in 2004, and which involves the use of the 34m diameter NASA Radio Telescope at Robledo de Chavela (Madrid, Spain) to disseminate Radio Astronomy among high-school and University students [28]. Like other Spanish professional Astronomy institutions such as IAA [29] or IAC [30], these initiatives make use of professional and large Radio Telescopes with the aim to make public their facilities and divulgate Radio Astronomy to society. On the contrary, the initiative proposed and carried out at the UPCT

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has an academic origin, with the main objective to stimulate the potential and improve the learning process of our graduate and postgraduate students in the fields of Electromagnetism, Antenna and Microwave Engineering, and Signal Processing. In the international picture, similar university projects can be found at MIT Haystack Observatory (Boston, MA) [31], Cardiff University (UK) [32], or Saint Mary's University (Canada) [33]. Nevertheless, a secondary objective and interesting consequence is the application of this project to share this amateur SRT between high-school students, local Astronomy associations and society in general, trying to attract new students to our faculties and improve the interest of young people for Science and Engineering. A similar task in an international level can be attributed to the SETI (Search for Extra Terrestrial Intelligence) team [34], in his aim to let individuals collaborate in this search, with projects as the SETI@home [35] or the development of amateur SRTs for SETI Argus Project [36-37].

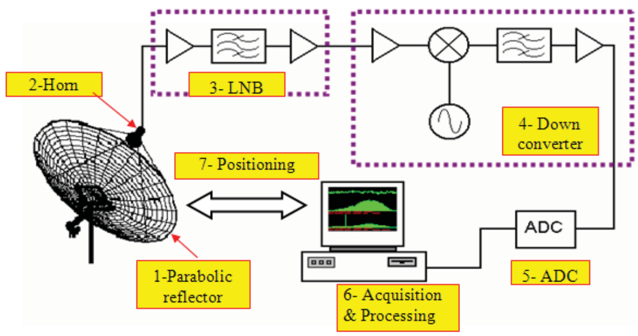

Figure 2. Scheme of the Radio Telescope subsystems

In this paper, the particular objectives of the SRT project undergone at the UPCT will be described, illustrating the methodology used to improve the learning process of the aforementioned undergraduate and postgraduate courses. Also, the response of the students and the results obtained will be addressed, together with the main future lines.

II. Objectives and Benefits

The main objectives of this initiative, and the associated benefits for the students, can be summarized as follows:

1- **Development of a small radio telescope (SRT)** capable of detecting the **L-band emissions of atomic hydrogen** (1.42 GHz). This frequency was chosen since the hydrogen line emissions from our Galaxy are quite abundant and relatively strong [11]. Moreover, this microwave range provides understanding of high-frequency related phenomena studied in Antenna [5-6] and Microwave [7-10] Engineering without overcoming the 6GHz band, in which the manufacturing and testing of circuits and antennas becomes much more expensive and difficult. Therefore, the microwave receivers working at this frequency are *relatively easier and cheaper to design and manufacture*, if compared with higher frequencies or more sensitive receivers, which might be impractical for modest tools and laboratories like the ones that our graduate students can use.

2- The system (see Fig.2) must be entirely designed, manufactured, tested, set-up and maintained by our students. In this way, the students face a complex project, in which ***practical, interdisciplinary, teamwork competences*** must be developed with a concrete target. In this way, we try to *make **the students realize of their actual developed abilities as future engineers***. It has been found that many students have the feeling of having developed too theoretical, poor practical skills in our Engineer faculties, feeling unprepared for real practical works [1,2]. Even if the lectures do not believe that this feeling corresponds to reality, it is good to make the students realize from and early stage about their actual abilities to face real, practical, complex, interesting engineering projects, so they feel more *motivated and confident*.

3- The SRT system involves different theoretical concepts which the students are supposed to have gained during their graduate and undergraduate courses (mechanics, physics, astronomy, electronics, electromagnetism, microwave circuits, antennas, signal processing, instrumentation…). In this way, we make the students develop ***interdisciplinary skills***, gathering the knowledge of all these courses together to face this work. We believe that this is a more realistic and practical position for them to face the real world, opposed to the academic perspective of “unconnected courses” so often addressed by graduate students.

4- Apart from being multidisciplinary, we also look for development of ***teamwork competences***, needed for practical big projects which cannot be faced by a single person.

5- Once the initial SRT has been set-up and installed at UPCT, it is intended to be a ***constant tool for teaching and upgrading***. The basic system provides an *excellent laboratory* to make *permanent improvements* and *develop future projects* in any of the associate disciplines and technologies. The idea is that the ***students of UPCT must feel fry to conceive and propose new project*** which might upgrade the performance of the SRT, working out their ***creativity and research abilities***.

6- A more *wide objective* is to use this SRT to ***attract young people and increase their interest in Sciences and Technology***[1]. Particularly, the SRT is intended to help in the recruitment of new students to our Engineering Faculties [2].

7- Radio Astronomy is not as spread and known in society as its optical counterpart, probably due to the complexity associated to microwave circuits and antennas. The SRT has also the *social objective* of **introducing *students and amateur astronomers to Radio Astronomy and linked technologies***.

III. Methodology

To face objectives 1-5, some UPCT lecturers started by the end of 2004 a set of BsC and MsC final projects, which were supported from 2006 to 2008 by a Regional Foundation project [38]. The methodology was based on the division of the whole SRT system in several subsystems, as illustrated in

Fig.2. In this way, each student could choose the SRT subsystem he or she wanted to work at, either in the initial design or in the continued upgrading. Obviously, the student and the supervisor should be aware of the state of other SRT projects, improving the result of previous projects and responding to the necessities of current works undergone by other colleagues. A total of **4 lecturers and 32 students** got involved from 2005 to 2009 in the development of the different subsystems of the SRT, with an **average extent of 9 months** (one course) per project.

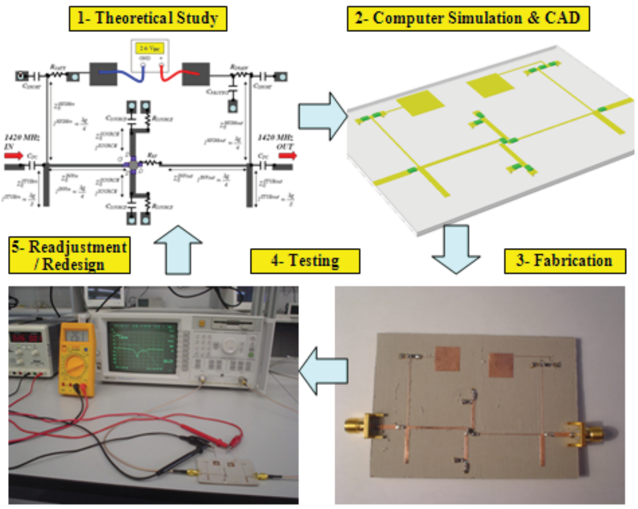

Figure 3. Scheme illustrating the methodology used in each subsystem project for the particular case of the SRT Low Noise Amplifiers (LNAs)

As it is shown in Fig.2, the SRT system is divided in the following comprehensive subsystems:

1- Parabolic Reflector

2- Horn

3- Low Noise Block comprised of:

- 3.1- RF Band Pass Filters
- 3.2- Low Noise Amplifiers (LNAs)

4- Down Converter comprised of:

- 3.1- Low Noise Amplifiers (LNAs)
- 3.2- Local Oscillator (LO)
- 3.3- Mixer
- 3.4- Intermediate Frequency (IF) Filters

5- Analog to Digital Converter (ADC)

6- Acquisition & Signal Processing

7- Control of Motors for Positioning and Tracking

It must be noted that each of this subsystems, although connected and dependent each other, have an individual particular function, which corresponds to a type of hardware signal processing. Moreover, these subsystems practically cover most of the type of circuits used in analog microwave systems [10], so that the SRT receiver scheme in Fig.2 can be **generalized to many other applications concerning Telecommunication Engineering** and Microwaves for Industrial, Scientific and Medical Applications [7,8]. All the students must have, therefore, a broad perspective of the overall receiver system, and at the same time a more meticulous standpoint of the subsystem they are in charge of. In this way, it is promoted the ***interdisciplinary and teamwork competencies***, and a broader knowledge of radio communication systems. The basic methodology of each subsystem project is illustrated in Fig.3, consisting of several steps:

a) **Theoretical study** of subsystem, using the associated disciplines textbooks [3-10], and particularly one text book developed by the supervising lecturers [39].

b) **Computer aided design** (CAD) and simulations using commercial software, such as *Ansoft High-Frequency Structure Simulator* HFSS [40] for linear electromagnetic three dimensional simulations, *Agilent Advance Design System* ADS [41] for linear electromagnetic planar circuit simulations, *Applied Wave Research Microwave Office*-MWO [42] for microwave circuit linear and non-linear frequency analysis, and *Orcad PSPICE* [43] for microwave circuit non-linear transient time-domain analysis. Depending on the type of subsystem, the student might have to use one of these packages (or a combination of them), so that the her or she must learn the main differences, similarities and applications of each one of these **commercial microwave CAD tools**.

As descriptive examples, Figs.3, and 4 illustrate the microwave circuit CAD with MWO for the LNAs and the mixers, respectively. Figure 5 shows an example of microwave transient analysis of the microwave local oscillator (LO) using PSPICE. Finally, Fig.6 depicts the electromagnetic CAD of planar microstrip RF filters, while Fig.7 illustrates three dimensional electromagnetic CAD of the horn of the SRT employing HFSS CAD.

c) **Physical design** of actual prototypes using the more convenient technology. Particularly, planar microstrip PCB (Printed Circuit Boar) technology [9] has been used for most of the microwave circuits (LNAs, RF filters, LO, mixers, IF filters), while waveguide technology has been used for some of the RF filters [4] and the horn antenna [6]. In this way, the students have to face different **practical microwave technologies**, understanding their advantages and drawbacks.

d) **Fabrication of the prototypes** in the corresponding technology using the more appropriate processes, such as photolithography for printed circuits or drilling and mechanization for waveguides and horn antennas. The students gain at this stage a novel **practical perspective about manufacturing processes** (possibilities, limitations, applications), which usually have not been gained in previous courses.

e) **Testing of the circuits**, using the RF instrumentation available in the laboratories. Again, depending of the particular subsystem and technology, different types of measurements and instruments might be used, such as DC voltage supplies, RF generators, spectrum analyzers, network analyzers, RF probes and oscilloscopes. This part is also very interesting for the students, since they **deal with real instrumentation** which is not used in many theoretical courses.

f) After comparing the results of their experiments with the theoretical design and CAD simulations, it is quite common that the student must make some **readjustments and even redesign the circuits** to improve the performance of the actual designs. In this stage, the students learn the difference between the world of CAD model and the real world, understanding also the **importance of using accurate and efficient electromagnetic/electronic simulation tools**.

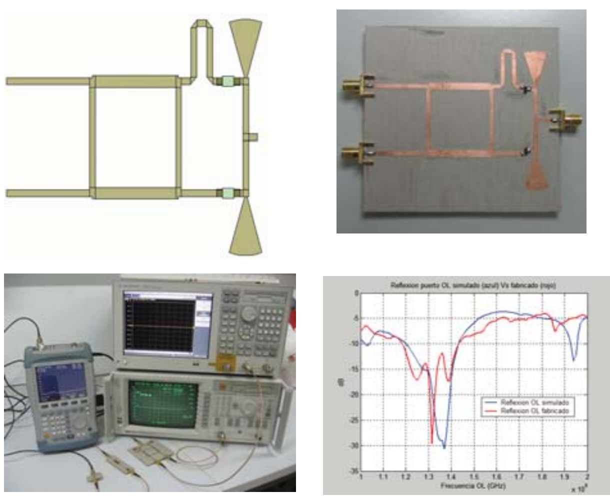

Figure 4. Development of the SRT microstrip mixers

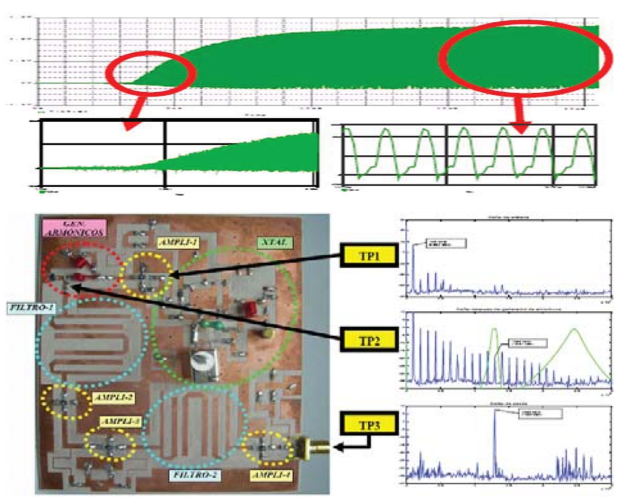

Figure 5. Development of the SRT microwave local oscillator.

Figures 3-9 schematically show some examples of this methodology applied to several of the subsystems of the SRT (LNAs, mixer, local oscillator, RF filters, horn, parabolic reflector and positioning subsystem). Moreover, it must be said that in these four years of work, several improved versions of each subsystem have been designed, so that the students collected the work done in previous years by older colleagues, and worked hard to progress for the better performance of the whole SRT. We believe that this method is very instructive and encouraging for students, since they feel that they are part of a big project in which many people are involved in **teamwork** trying to design the complex system.

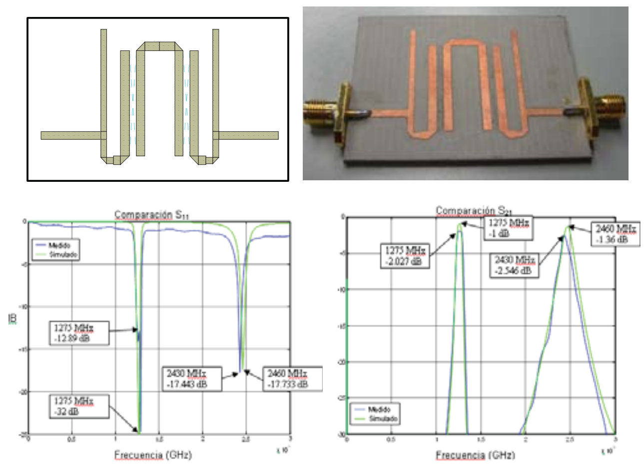

Figure 6. Development of the SRT microstrip band pass filter

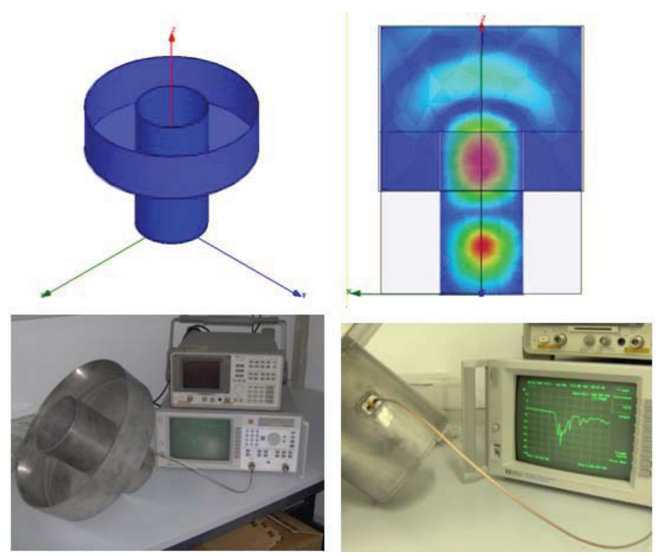

Figure 7. Development of the SRT horn feeding the parabolic reflector

Particularly interesting was the design of the parabolic reflector and the positioning system, shown in Figs.8-9, since they mixed up **interdisciplinary work** involving mechanics and high-power engineering. Another interesting part for the students is the assembly of the different subsystems to conceive the **whole RF receiver** (Fig.2 and Fig.10). For this purpose, especial RF system analysis CAD (*Applied Wave*

Research Visual System Simulator VSS [44]) was used, as illustrated in Fig.10. The same aforementioned methodology is applied for the development of the whole RF receiver, with the particularity that the student must have a deep knowledge of all the RF subsystems involved, which where designed in previous projects. Also, the fabrication and testing of the entire RF receiver is more complicated, since the students must deal with a more complex board and several RF subsytems.

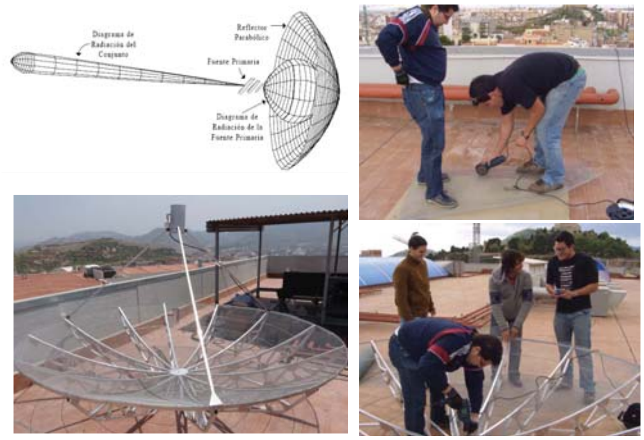

Figure 8 Development of the SRT parabolic reflector

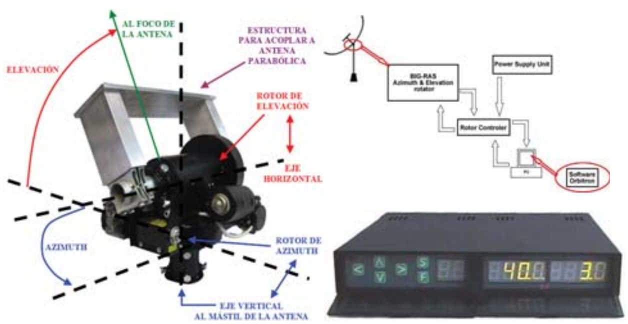

Figure 9. Development of the SRT positioning subsystem

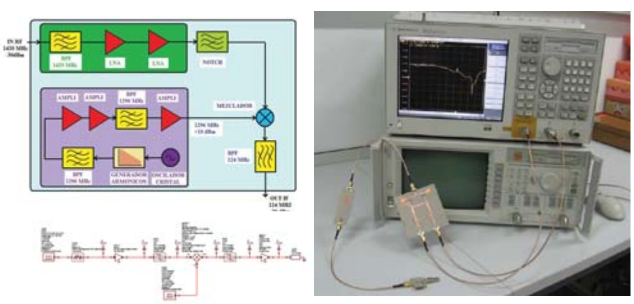

Figure 10. Development and assembly of the whole SRT RF receiver.

The emplacement of the engines and antenna was also very instructive and entertaining for the students, as shown in Fig.11. All participants were very excited to see the SRT located at the final position. For this stage, a solid and stable post was designed, fabricated and sited in the roof of one of the buildings of the University [45]. Finally, the engines were placed on top of the post, and the reflector together with the horn and some LNAs were assembled to it. The students made careful experiments at this stage, in order to properly place the horn at the focal point of the reflector, as shown in Fig.12. A final picture of the SRT from the outside of the building at UPCT is shown in Fig,13.

Figure 11. Emplacement of the engines and antenna at post.

Finally, a web-page has been created to hold and share updated information of this project [46], including general information about Radio Astronomy and Microwave and Antenna Engineering. Particularly, this web page holds all the technical reports derived from the students' MSc projects, including powerpoint presentations and some interactive applets, which might be useful for other people interested in amateur Radio Astronomy.

Figure 12. Assembly of the horn at the parabolic focal point and tests.

Figure 13. Final emplacement of the SRT at UPCT.

IV. RESULTS AMONG THE STUDENTS

To evaluate the degree of success of this initiative, with respect to some of the objectives described in Section II, several questions were addressed to the students (a total of 32), once they had finalized their project for the SRT. The questions are summarized below:

1- Do you think working in this project has made you improve your practical abilities? *(Not at all, Not sure, Sure)*

2- Do you think this project has been relevant in your formation as a future Engineer? *(Not at all, Not sure, Sure)*

3- Do you think that this project has been relevant to better understand the associated disciplines that you studied in previous courses (microwaves and antennas)? *(Not at all, Not sure, Sure)*

4- Do you think that this project has improved your teamwork skills? *(Not at all, Not sure, Sure)*

5- Do you think that this project has improved your motivation and interest about the degree you studied? *(Not at all, Not sure, Sure)*

6- Do you think that this type of projects could substitute the associated theoretical courses? *(Not at all, Not sure, Sure)*

All the students responded to questions 1-5 with the "*Sure*" answer, showing an **excellent degree of success among the students** with respect to objectives 2-4 of Section II. It is interesting to note that 53% of the students answered "*Not at all*" to the last question, a 31% answered "*Not sure*" and the remaining 16% answered "*Sure*". Obviously, this project is not intended to replace the theoretical courses, which in opinion of this lecturers are indispensable for the students in order to face the more practical projects proposed in this SRT initiative (as 53% of the students addressed).

From the lecturers' point of view, it is being a satisfying experience (despite the big effort and time of dedication needed to supervise these projects), since the students showed high degree of interest and satisfaction, presenting own judgement and clever ideas, and yielding fruitful discussions and enhancement. Therefore, we really believe that this initiative strongly improve the learning process of the associated Microwave and Antenna Engineering courses, and it is extensible to any other Engineering course. The main condition is to find a practical and interesting application (in this case Radio Astronomy), making the students face an appealing Engineering task to develop their highest potential.

V. CONCLUSIONS AND FUTURE LINES

Objectives 6-7 of Section II can only be achieved after the SRT is used for **dissemination between high-school students and astronomy amateurs in the future**. Particularly, the first future line is to calibrate the SRT to be able to map our Galaxy, so that appealing results as the hydrogen line map shown in Fig.14 can be obtained and shared with visitors.

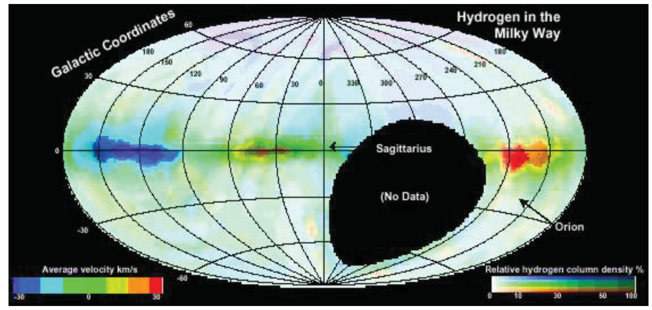

Figure 14. Hydrogen line map of our Galaxy.

Objective 5 is a consequence of the success of the development of the SRT initial system and the good response of the students, so that **this SRT will be used by the students to upgrade its performance and propose new applications**. One of these future upgrades might be the design of an interferometer radio telescope (Fig.15), or the development of receivers and antennas working at other frequencies to detect other interesting signals from our Solar System and Universe. Moreover, the SRT is intended to participate in the SETI project [34,36], which can be another attractive application to increase the interest among the young students and future graduates.

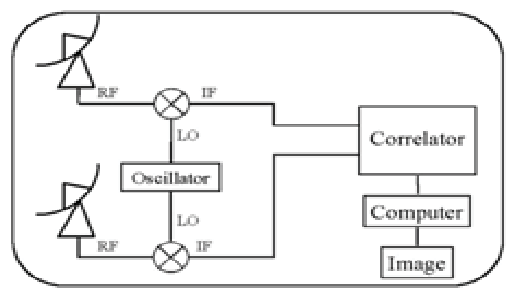

Figure 15. Scheme of a basic linked radio interferometer.

Nevertheless, the authors of this work believe that this type of initiatives are not given enough importance by the actual academic system, which mainly score the lectures by their research results. This fact makes that the endeavor of University lecturers is set on pure research, not being worthy to waste time and energies carrying out dissemination projects like this one which might not be valued in accordance to the effort needed. However, the authors of this paper believe that these enterprises are of key importance to the future of Science and University, and moreover they are a duty with our students and society.

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Session 06C Area 1: Collaborative and Social Technologies - Experiences

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Applying a Methodology for Collaborative Assessment in Learning Groups

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***Abstract*— Collaborative evaluation is still a less explored subject within the collaboration field. This paper proposes a methodology to collaborative evaluation based on the 3C collaboration model, which can be applied both in learning or working groups. This paper also presents two case studies run on graduate courses of the Computer Science Department of Catholic University of Rio de Janeiro for collaborative evaluation of the students work. The case studies suggest that the methodology is appropriate for this type of assessment. In addition, students participating in the experiment rated the experience as positive, confirming the premise that students value and miss the collaborative evaluation.**

Keywords- Collaboration, Groupware, Collaborative Evaluation, Assessment

I. INTRODUCTION

Collaboration is a process by which individuals negotiate and share relevant insights to solve a problem. It is a coordinated and synchronous activity, result of a continuous attempt to construct and maintain a shared understanding of a problem [9].

In collaborative learning, the student is responsible for his/her own learning, and collaborates with the other group members' learning, constructing knowledge through reflection on group discussion [5]. The active information exchange instigates interest and critical thinking, allowing learners to reach better results than by studying alone. In collaborative learning, the teacher shifts his/her role from authority to supervisor.

Computer Supported Collaborative Learning (CSCL) studies how people can learn in groups using computers. This approach proposes the development of new software that allows group learning and offer creative activities of intellectual exploration and social interaction. CSCL is often combined with e-learning, which can be defined as organizing instruction using computer networks, like the Internet [10].

Due to the collaboration between participants, the traditional assessment methods-- in which the teacher prepares a written test and the student must answer the questions correctly-- are insufficient to measure the results of collaborative learning. Much like the learning process, the assessment should itself be collaborative, thus allowing the evaluated student and their colleagues to contribute to the assessment process, which is no longer the sole responsibility of the teacher.

The research presented in [3] illustrates how the students consider and miss collaborative assessment when it is not used. In the words of the learner of an online course that suggested the proposal:

"Evaluating is a very interesting activity. We can reflect, analyze, consider… a lot of other reasons could be listed to justify this activity; to assess the other and yourself. I don't understand why this deliciously cognitive activity – to evaluate – is an aspect restricted to teachers (…) See how simple it would be if, at the end of each message, a field were available at the same site for you (the learner) to evaluate by giving a grade and commenting."

[8] points out that, for teachers, student evaluation has always been challenging, and it is difficult to understand the real level of conjecture of the student learning. In addition, states that the evaluation is still a cause of anxiety in both teachers - because there is a concern about quality, loyalty, fairness, integrity, trustworthiness, privacy, efficiency and honesty of the evaluation - and in students - due to fear, insecurity, humiliation, distrust, anger, rage and tumult of the evaluation.

When students share the responsibility of evaluation, the comprehension and the utility of evaluation increase [7][6]. To the evaluated ones, having several assessments of their work increases confidence on the results of the evaluation. Additionally, the evaluators better understand the process and the objectives of the assessment, thus increasing their critical sense and ability to improve on their own work.

Despite the evidence of the benefits of collaborative evaluation, the literature still suffers from the lack of a methodology for conducting such assessment. To fill this gap, this paper proposes a methodology based on the 3C Collaboration Model. Section 2 presents a summary of the 3C model and section 3, the steps of the proposed methodology. Section 4 describes the application of the methodology in two case studies and Section 5 provides a analysis of the participants. Section 6 assesses the proposed methodology based on the results of case studies and finally section 7 presents the conclusions of the paper.

II. THE 3C COLLABORATION MODEL

To collaborate, individuals should exchange information (communication), organize themselves (coordination) and operate together on a shared space (cooperation). The exchanges that occur during communication generate commitments that are managed through coordination, which organizes and disposes of tasks that are executed in cooperation. When cooperating, individuals need to communicate in order to negotiate and decide about unexpected situations. Finally, through perception, the individual is informed about what is happening and obtains information necessary to his/her work. The diagram in Figure 1 summarizes the main concepts discussed. This diagram, proposed in [4], is a refinement of the 3C model originally presented in [1].

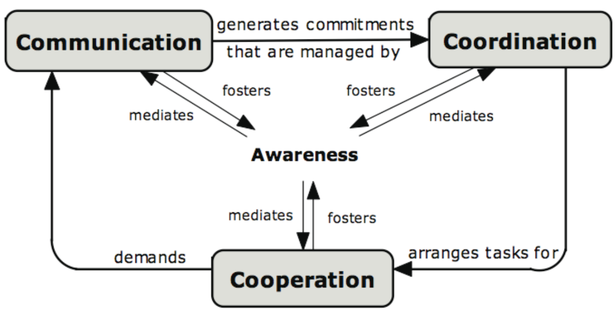

Figure 1. The 3C Collaboration Model

This section presented the theoretical concepts that were the basis for this research. The next section presents the proposed methodology for supporting collaborative evaluation in learning or working groups.

III. THE METHODOLOGY FOR COLLABORATIVE EVALUATION

The methodology for collaborative evaluation proposed as follows defines the necessary steps for the preparation, implementation and dissemination of evaluation results. It is important to emphasize that its use is not restricted only to the educational field. It can also be applied, for example, to evaluate scientific papers for publication at conferences or in the evaluation of corporate projects by coordinators, clients or stakeholders. The following are the steps of the methodology.

1. Definition of assessment sources

At this stage, should be defined according to the application scenario, what are going to be the sources of evaluation, i.e., which actors will effectively play the role of evaluators. These actors should be grouped according to their profile, for example, teachers and students, in the case of an assessment of scholar work in the classroom; or coordinators, peer developers and customers, in the case of an assessment of a corporative project to develop a system. At this stage, it should be determined if the self-evaluation is going to be included or not.

2. Defining the type of evaluation: Qualitative, Quantitative

In this step, we must determine whether the assessment will be qualitative (assessment through comments), Quantitative (assessment by assigning concepts or notes) or mixed.

3. Analyzing the domain for developing the evaluation criteria

The domain in which assessment will be applied needs to be analyzed to define the appropriate evaluation criteria. For example, should be considered if the assessment is in academic or corporate environment. When in an academic environment, for example, it should be considered the course level (undergraduate or graduate), the objective of the work to assess, if it is individual or in groups, and other factors. For each criterion must be chosen a type of evaluation among those defined in step 2.

4. Grouping the evaluation criteria in templates and associating evaluation sources

Defined the evaluation criteria, we must group them into templates that are associated with the assessment sources defined in step 1. A template is a set of criteria that can be represented by an evaluation form. Each source must have an evaluation template associated to assess a work, but the same template can be shared between more than one source of evaluation.

5. Defining the composition of the final grade

The next step is to define how the final grade is calculated: which criteria will be considered, and the weight of each one. We can also define weights for each of the sources of evaluation, according to the analysis of the field. This step is optional because in some cases a final grade is not the purpose of the evaluation.

6. Defining the mechanisms for conflict resolution

This step is focused on analyzing the assessments to check for possible conflicts, which means differences between assessments that may indicate that some of the two assessments was not done properly. The aim of this step is not necessarily reach a common assessment, but do evaluators consider the arguments of the conflicting evaluations to confirm that the reviews are really different or if there was any error in the judgment. This procedure aims that the final evaluations are most appropriate and consistent with reality. Thus, it should be set for each domain what characterizes a conflict, and how it will be resolved.

7. Defining the format of the final evaluation report

It must then be defined how the results of the evaluation will be presented to the assessed ones. It is recommended the use of a consolidated report showing the evaluation by criteria (you can choose to display all the evaluations received for each criterion, or just the average received on each criterion) and the final grade, if applicable. In this stage, the planning stage of the activity of collaborative evaluation is closed.

8. Presenting the work to be assessed

In this step, the implementation phase of the collaborative evaluation starts, according to the steps 1 through 7. According to the case, the work to be evaluated can be made both synchronously (e.g. oral presentation with PowerPoint slides) or asynchronously (e.g. work submission via e-mail to the evaluators).

9. Assessment

After presenting the work to be evaluated, the evaluators should use the appropriate template to perform the evaluations. This step can be done through a paper or electronic, form or with the support of a system.

10. Disseminating Results

Then, the evaluation results should be disseminated as appropriate for each area. The evaluation report defined in step 7 should be submitted to the evaluated ones, and depending on the case also for evaluators too (for example, in the academic environment, for teachers and in the case of the corporate environment for leaders or coordinators).

For the conception of this methodology, it was considered as the theoretical basis the 3C model presented in section 2 of this article. The model shows the importance of communication, cooperation and coordination for effective collaboration. Next, we show how each element was considered in developing the methodology proposed in this paper:

Communication: should occur in the presentation of the work to be evaluated (step 8). It is also very important in the step of conflict resolution of the evaluation (step 6).

Cooperation: it is present in the process of collaborative evaluation in itself, in which a group of evaluators using a shared model assess the same work. Evaluators cooperate participating in the evaluation process, in order to reach a common goal - the end result of the evaluation.

Coordination: the whole process of collaborative evaluation can only occur if there is coordination between all parties. You must dictate the rules of the process for the assessed to present the work to be evaluated and for the evaluators to assess it properly. All participants must have a clear understanding of its role in the process. It is desirable to have a central figure in coordinating the process for best results.

IV. Case Studies

To validate the application of the methodology proposed in this work in collaborative evaluation of academic work, 2 case studies were performed in graduate classes of the Pontifical Catholic University of Rio de Janeiro (PUC-Rio). For each case study, we used an instance of the framework IssueNet, described in detail in [2]. The main module of the system is a task manager that implements a workflow for creation, assignment and assessment of tasks. Thus, the system calculates the final grade of an activity from the tasks related to it, using specific criteria reported by the user. In the following subsections will present the case studies.

A. Case Study 1

The course "Project of Software Systems (PSS)" is offered by the Computer Science Department of PUC-Rio in the area of Software Engineering, and is attended by students in undergraduate and graduate levels. This case study was conducted during the final work, in which students should develop a framework and implement an instance on an issue of free choice. The theoretical concepts learned in the course must be correctly applied to the work. Weekly, each student must present to the class the progress of his/her work. The presentation is in Power Point format and should address the scope defined by the teacher in the course schedule. The other students have only to attend to the presentation whereas the teachers have to evaluate it. At the end of the semester when each student presents the complete work, the grades of the weekly presentations are taken into account in calculating the student's final grade.

The case study was to examine the application of the methodology proposed in this paper to conduct collaborative evaluation with participation of students, and was used in a class of 11 graduate students. In subsection C, will detail how the methodology has been applied to this case study in particular.

B. Case Study 2

To confirm the results obtained in the case presented in subsection A, the methodology proposed in this paper was also applied in a case study conducted with 43 students and two teachers in a different graduate course in PUC-Rio.

Among the activities of the course, students must present orally and in groups of up to 5 members, a work about design patterns. The works are presented to the teacher and the whole class. In previous classes, the evaluation of the work was done exclusively by the teacher using her own criteria. In this case study, this assessment was made collaboratively, and more than one teacher participated in the evaluation.

C. Applying the Methodology

The methodology proposed in section 3 was used for the elaboration of the assessment activity of the two case studies. The following are detailed how each step of the methodology was applied to each case study.

1. Definition of assessment sources

For both case studies was determined the use of 2 sources of evaluation: evaluation of the professors and students (peer review). Specifically in the case study 2, one work was evaluated both by members of the group (self-evaluation) and by the other students in the class.

2. Defining the type of evaluation: Qualitative, Quantitative

In both case studies were used both qualitative and quantitative evaluation. In case study 1, for each criterion should be assigned a grade from 1 to 5 (quantitative assessment) and a comment (qualitative assessment). In the case study 2, it was determined that the evaluation would be primarily quantitative. For each criterion of quantitative evaluation, should be assigned one of the following concepts: Poor, Weak, Fair, Good, Excellent. These concepts have been mapped in grades from 1 to 5 to facilitate the calculation of the final grade. To complement and enrich the evaluation, a field of general comments would be available with optional padding, representing the qualitative assessment.

3. Analyzing the domain for developing the evaluation criteria

In case study 1, the purpose of the work was to develop a complete framework, from modeling to programming. Each student presented his work in three phases of an hour each. In the first week (phase 1) should be presented the definition and application requirements. In the second week (phase 2), the goal was to present the computer modeling work. The third and last week (phase 3), the goal was to present the complete system, running. To this end, 5 criteria were developed for each phase such as Definition of the use case requirements (Stage 1) Formulation of Diagram of Classes and Sequence (Stage 2) and Integrated presentation of the various aspects of solving the problem (Phase 3).

In the case study 2, the purpose of the work was the creation, modeling and presentation of a social networking site using 3 design patterns seen in class, chosen by the group. The duration of the presentation should be a maximum of fifteen minutes. Five evaluation criteria have been developed: Adequacy of the presentation on the time available, Quality of slides and oral presentation, Creativity of the system and of the chosen patterns, Appropriateness of the patterns to the system and Correct application of the concepts.

It is important to say that in both case studies, it was established the criterion General Score, which represented the final evaluation of a work. This criterion will be further detailed in step 5.

4. Grouping the evaluation criteria in templates and associating evaluation sources

In case study 1, we decided to create a single template containing all the assessment criteria, and assign it to both students and teachers. In case study 2, were created 2 templates: one for teachers and one for students, the latter also used in self-evaluation. For the template of the students, we chose to use the criteria more focused on the presentation itself, and not in evaluating the theoretical knowledge presented. For the template of the teachers were used both criteria for evaluating the presentation and criteria for evaluating the application of theoretical concepts.

5. Defining the composition of the final grade

In both case studies, all the evaluators were asked to evaluate the criterion General Score with the grade that would effectively be taken into account in the calculation of the final evaluation of students. This value should not necessarily be the average of the grades awarded in other criteria (whose function is to enrich and detail evaluation), but the general score that the work should receive, in the opinion of the evaluator. The composition of the final grade of each job was also the same for the two case studies. It was calculated as 0.7 * average of teachers grades + 0.3 * average of students' grades. We decided to use this formula because of the limited experience of evaluation that, in general, the students have.

6. Defining the mechanisms for conflict resolution

In both case studies, it was decided that a conflict would be characterized by a difference of 3 or more points in the evaluation of certain criteria. For example, if on the criterion C1 the Assessor A1 has assigned “Weak” (or grade 2) and the Assessor A2 has assigned “Excellent” (or grade 5), it would be characterized as a conflict. In case study 1, it was decided that the conflict would be resolved through tasks designed for conflicting evaluators inside the IssueNet. In the case study 2, it was decided that the conflicting evaluators would be called by e-mail to clarify their evaluations.

7. Defining the format of the final evaluation report

In case study 1, the final evaluation report of a work could be consulted through the system IssueNet. This report showed in detail all the grades and comments received at each stage of evaluation, and the final grade of the work. In the case study 2, because it had simpler templates, we chose to send a spreadsheet showing all the concepts, comments and the final grade of the work.

8. Presenting the work to be assessed

In both case studies, the work was presented orally and was used PowerPoint to present it. In case study 1, the work is individual and only one student made a presentation, while in case study 2, each group decided if would be one or more presenters.

9. Assessment

In case study 1, the evaluators conducted the evaluations directly in the IssueNet system. In case study 2, due to limitations in the classroom in which there were presentations, the evaluators conducted assessments on paper forms and then the teacher recorded the evaluation forms on the IssueNet system.

10. Disseminating Results

In case study 1, the final evaluation report was published on the IssueNet environment for consultation by both evaluated and evaluators. In the case study 2, the evaluated students received by e-mail the same report generated by IssueNet.

V. ANALYSIS OF PARTICIPANTS

In case study 1, when asked about the collaborative process of assessment, most students approved the experience. Most students (85%) said that compared with traditional evaluation, in which only the teacher evaluates, the collaborative evaluation is good or excellent, and they also agreed that to evaluate their colleagues helps to hold attention in class and learn the theoretical concepts of the discipline. While 70% of the evaluators agreed that the peer evaluation helps improve their work, 15% expressed as neutral. When asked whether to evaluate their colleagues causes the evaluator feels playing a more important role, 57% agreed, 15% were neutral and 28% disagreed. Students also pointed out that the collaborative evaluation facilitates interaction between students and allows direction of efforts in light of the weaknesses of each.

In case study 2, the majority of students also approved the experience of collaborative evaluation: 81% enjoyed the experience. When asked to compare this practice with the traditional evaluation, 86% rated collaborative evaluation as good or excellent and 72% said that the evaluation of their colleagues helps to hold attention in class and learn the theoretical concepts of the discipline. When asked if to evaluate their colleagues causes the evaluator feels playing a larger role, 78% agreed, 6% were neutral and 16% disagreed. As in this case study only 45% of students enriched the assessment of colleagues with comments beyond the simple allocation of concepts, they were asked why, and most (75%) claimed that the evaluation criteria used were already sufficient for a proper evaluation.

VI. Methodology Assessment

After completion of two case studies, it was found that the collaborative assessment methodology was well accepted in both groups. Below some important points extracted from the evaluation of case studies are highlighted.

In case study 1, students said that by having to evaluate their colleagues they pay more attention to the presentations, what helps to identify improvements and best practices that can be applied to their own work. They also stressed that the collaborative evaluation facilitates interaction between students and allows the direction of efforts in the light of the weaknesses of each. Thus, the collaborative evaluation allowed students to add value to the work of colleagues, and in fact the progress of work using the contributions received during the ratings it was actually perceived. However, students stressed that they would like to have discussed the assessments more in order to share opinions, to understand better the rating received by colleagues, to establish better theoretical concepts of discipline and to enrich the learning of the group with the exchanged ideas. Thus, there are indications that a stage of discussion of the assessments should be included in the methodology to achieve greater use of collaborative evaluation.

In the case study 2, the collaborative evaluation was seen by students as a way to better understand the assessment process and thereby enable a self-assessment in order to improve their own work. They also stressed the advantages of being able to exercise the critical thinking of each one playing the role of assessors, increased interaction between students and an evaluation with different points of view and more complete than the traditionally received only from the teacher. In addition the students absorb better the concepts of discipline paying more attention to the presentations of the work. Although the students felt motivated by the responsibility to assess their colleagues in a fair, impartial and serious way, they were concerned in making sure that all colleagues would have this right feeling. Thus, strategies should be investigated to incorporate into the work a change in attitude on the part of evaluators, emphasizing their responsibility to contribute to the grade of a task.

VII. Conclusion

This paper presented a methodology for collaborative assessment based on the 3C Collaboration model that can be applied both in working or learning groups. Two case studies taken in graduate courses of the Informatics Department of PUC-Rio for collaborative evaluation of academic works suggests that the methodology is appropriate for this type of assessment. In addition, students participating in the experiment rated the experience as positive, confirming the premise that students value and miss the collaborative evaluation. In future work, we intend to evaluate the application of this methodology in different scenarios, for example, in evaluating corporate projects, and investigate solutions to fill the gaps identified by case studies.

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Web 2.0 contents for connecting learners in online Learning Network

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Abstract— **The paper proposes a conceptual model for designing a people-finding system in a Learning Network. The system is intended to help a learner in getting recommendation about suitable people who are interested on a similar topic and share common learning goal with the current learner. We propose that by using the user-generated (text) content, social-bookmarking and social-tagging, driven by Web 2.0 approaches, we can implicitly profile people and find people's interests on a given topic. We also like to use their existing social connections as an evidence to select suitable people in recommending a learner.**

Keywords-recommendation systems; web 2.0; social matching; learning technology; social support system; people-finding systems; learning network; informal learning

I. Introduction

Paul is a student of education sciences, he needs to write a project paper on the topic of "education and technology". Suppose he wants to draft a report on the uses, benefits, roles and implications of the Information and Communication Technologies (ICT) in education. He can start his search on internet and find a plethora of websites, research papers, blog-posts, bookmarks and other electronic resources that could help him to achieve his learning goals. The search will give him enough information, hard enough to decide himself their relevance. On the other hand, he is also interested to connect to people having experiences, interests as well as expertise in the area of "Educational Sciences and Technologies", he can ask for their help, suggestions, build up social connection and share knowledge. In this paper we are interested to bring in attention of a specific class of people-finding systems which are meant to recommend people who are associated, have specific knowledge or interests in a given domain. The problem which motivates this research is inspired by the following comment:

"When I have a question or a problem, I want to be able to immediately figure out who is willing, qualified, and able to help me solve it. Since the problems and questions come in every shape and size, some sublime, some ridiculous, I want my Instant Knowledge System to help me distinguish and locate an appropriate trusted source – an expert"

Dennis D. McDonald, excerpt from "Bringing Knowledge, Relationships and Experts Together"

What is referred here as an Instant Knowledge System, generally means a type of system to find people having knowledge in a problem domain. The problem of identifying people "who know something relevant" to the needs of information seeker is very relevant in an online Learning Network. Formally, a Learning Network is defined as an online network to support the learning needs of lifelong learners in a particular knowledge domain [1]. A Learning Network supports heterogeneous people of different age groups, expertise-levels and interest, to fulfill their learning goals. Learning Networks are meant for self-directed learners [2] who make their own learning plans, according to their learning needs, irrespective of place, time and pace of learning [3]. In such a Learning Network, very likely a learner would remain hidden from others even though s/he matches with others in common interests or knowledge. In particular, while performing a learning activity s/he needs to know about other learners who may provide her/him with support, advice or help. Research has shown that, learners' success or failure on a learning activity also depends on how well they are connected to other learners [4, 3]. In a situation where a learner searches for people, s/he needs to manually browse through the profiles or websites of individuals to get to know about others. It is a time taking and tedious job to manually browse through peoples profiles, especially in a large network of people. This also leads to increase the extraneous cognitive load [5], the efforts required by learner to gather information relevant for learning from disparate sources. A people-finding system in Learning Network would help to automatically search and suggest learners whom they match. Thus, we initiated research for designing and developing to find suitable others for a learner: a people-finding system, we call it as Social Support System (SoSuSy) in Learning Networks. In this paper we want to report about the approach we want to take, methods we want to use and the current state of work to develop a first prototype of SoSuSy.

II. PEOPLE FINDING AND RELATED SYSTEMS

People finding systems are a class of recommendation system meant to find a person who has knowledge on a specific problem domain [6]. There have been many efforts till date to realize such systems in locating people or expert [7, 8, 9, 10,

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11, 12, 13]. These systems use different techniques and have addressed different scenarios like answering a specific question, expert location for sharing advice, visualizing the competence of organizational groups etc. Typically, these systems use information from different range of sources like centrally held database of personnel skills [14], to systems that use real-time information held within the corporate system [15]. There has been development of people-finding systems that use an organization's common set of resources, including e-mails, phone books and peer-reviewed technical report repositories to identify the required expert [16]. Most of the expertise finding systems are system-centered since they use specially created data-bases containing people's profiles, maintained by the organizations. The problem associated with these profiles is that they are not updated regularly and people do not have a control on the content. With the advent of Web 2.0 and Social Software, people can bring in their content to the web using services like Blogs, social bookmarks, and social-tags (tag clouds) and they are able to build social ties globally with ease using social software (facebook, linkedIn, myspace etc.). Recent studies on the existing expertise finding systems have identified the need to focus attention on the user-generated content [17] and their social connections [18] to find experts. These information sources are publicly available and can help making open profile of people, showing their knowledge, expertise and interests. To address the limitations of previous studies and the avenues from the emerging web. We describe the basic conceptual model of our proposed system in the next section and suggest that by using the user-generated content (blog-posts, social-bookmarking and social-tagging), we can find people's interests on a given topic. We also like to analyze their existing social connections as an evidence to select suitable people in recommending a learner. With such recommendation service our intention remains in connecting people in a Learning Network to increase social capital, thereby increasing the productivity of learners by supporting interaction with others.

III. BASIC CONCEPTUAL MODEL

A. *Main Idea*

We attempt to design, develop and test a software prototype called Social Support System (SoSuSy) for the lifelong learners in the Learning Networks, (for general overviews please refer to our previous published work [19]). A system to find suitable people when the questions like "Who should I ask?" arises in a learner's mind. This research is an extension to the research efforts of providing a generic social help in an online community, similar to the expert finding systems in an organization, multi-agents learning support or virtual help assistants as reported in previous section.

B. *Social Support System (SoSuSy)*

In the current work, we are not only interested in experts search but also in any learner who is knowledgeable enough to help another learner on a particular question. We assume as a pre-condition, that people maintain their web presence by write about their interests (blogging), sharing bookmarks (tagging) and having social contacts (social network). They maintain the information online and let it accessible publicly. The advantage of open information is that anyone can reflect his interests (by using tags to associate with a concept, or social book-marking) and knowledge (blogging about a certain topic). By taking this information into account, search can be made to show fellow learners who might be suitable for giving a help request. A SoSuSy in Learning Networks would be an added value for a learner to know about people and decide whom to and how to interact with them. It will provide several benefits to a learner:

- A learner could connect and make social ties with other learners either for question in hand or for future contact in similar context.
- It is possible that in connecting people to other people, one can share and exchange expertise about the information which is not documented like people's experiences (tacit knowledge) and interests. A learner could share with others different perspectives on a topic, comparing and constructing meaning, which would lead to effective learning for her/him.
- A learner would not only depend on experts but s/he can seek help from any suitable person available in the Learning Network, where people with different levels of expertise exist.

C. *Web 2.0 content as a source for finding people*

The current internet provides several tools and applications (Web 2.0 applications), that make it easier for people to bring in their content to the internet. People in a Learning Network may already have online public information about their interests, skills, competence or knowledge, such information can be written as a free-text description on their web page, they might also write blog-posts which are then tagged to particular concepts and can be viewed as tag-clouds that indicate their interests. For example, people can write about their experience on "Scuba diving" and tag it with "diving" "underwater" etc, they can bookmark all the resources related to "diving". Such sources of information like bookmarks of interest, writings in the form of blog-posts, shows interests in the particular knowledge domain.

The user-generated content can be created in different forms like texts, videos, audios, pictures, documents. These are dynamic content (regularly updated) and provide latest information about people, like their working context, interests, knowledge, expertise and ideas. This information about people is relevant to suggest who is associated with which topic. The Social Support System will use the user-generated content which is a bottom-up information source about people, facilitated by Web 2.0 applications like web-logs (Blogs), wikis and social book-marking tags etc. There are several reasons to consider the user-generated content. First, as the use Web 2.0 applications are getting popular, it has become easier for people to maintain online information. People can write what they think about particular issues using Blog services (wordpress, blogger etc.) and categorize (by tagging) the Blog posts using keywords, bookmark their interests using social bookmarking services (furl, delicious etc.) and manage their social contacts (friends or colleagues) using social networking sites (facebook, linkedIn etc.). These sources of information are useful to make an open profile about people based on their interests, knowledge and competence on a particular topic. This information is valuable in addition to the evidence of people's competence formally stored in ePortfolios or in organizational records. Second, people need not be enforced by organization to follow strict structure to organize their personal profile, cases where information about people is maintained as log data in organizational repositories. Third, profiles maintained within organizational repositories do not always reflect people's knowledge and current interests, they become obsolete with time. Fourth, even when a new learner enters a Learning Network, s/he may already have existing information (blogs, bookmarks and social contacts). So we do not only depend on learner's information maintained during learning (e.g. completion of learning activities in a Learning Network) but we can make use of personally generated information (blogs, bookmarks and social contacts) about learners that reflect their learning achievements, knowledge, competence and interests performed before even joining a Learning Network. The challenge is how we can use the information from Blogs and tags to prototype a system for recommending suitable people to a learner in a Learning Network. We detail the process involved in identifying people to recommend to a learner. The process consists of three inter-related sub-process as follows:

For a given question of a learner to find people on a given topic:

1. We need to find the sources of information, which are relevant to the question. We call them key-concepts, represented by a set C.

2. We need to find people who use tags to associate with these key-concepts. This can be known by analyzing contents, namely; (a) People create their own content, e.g., by blogging. (b) People show interests in others content, e.g., by bookmarking.

3. We need to rank each person based on their association with key-concepts and social connection. We could then modify the results based on the social distance between the learners.

Each of the aforementioned points can be further elaborated. First, key-concepts may be represented informally as tags, blogs tagged with keywords, and bookmarks tagged with keywords. Second, there are people who are associated with these key-concepts, because they frequently use tags or keywords. The association means that they may have interests, knowledge, or skills about such a key-concept. People can either create their own content by writing about it (blogging, publishing etc.), or show interests in others content by book-marking with social tagging (e.g, del.icio.us). Third, social connection between people could provide information about people's network. Social connection could be based on friendship, co-working, partnership etc. Therefore, people who are socially connected and also working on a common topic may be recommended to a learner who are new to a topic. This description is illustrated in figure 1.

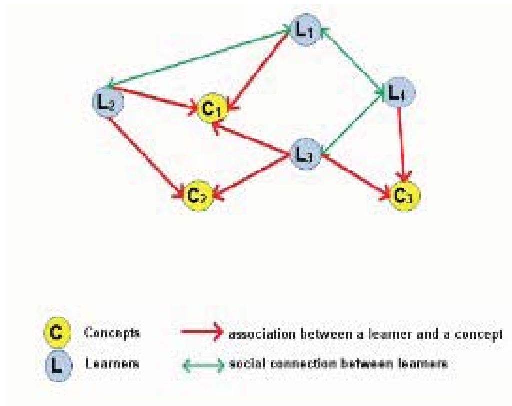

Figure 1. Associations between learners and concepts

In Fig. 1, learner L_1 is associated with the concept C_1 and has social ties with learners L_2 and L_4.

The bold (uni-directional) arrow indicates learners association with a given concept. They mean that the learners themselves make association (e.g. by using tags) with this particular concept. The bi-directional arrows indicate the social connections between the learners. A bi-directional arrow indicates that both learners are involved in getting in contact with each other by having common interests on a given topic (concept). Combining the three, namely; (a) key-concepts, (b) people's associated with key-concepts, and (c) social connections between them as depicted in Fig. 1, we could derive a model in terms of a simple equation to recommend a suitable person in a Learning Network. The rank of each person could be then based on their association with a key-concept and their social ties with fellows on similar key-concepts. We can also assign weights to the association to determine to what extent people are interested in a given concept. This will also reflect their expertise on that particular concept. The following equation shows the dimension to consider for implementing Social Support System.

*Rank of person = key-concepts * people associated with key-concepts * peoples' social connection*

D. Method used for requirements analysis

As the current state of work, we are doing requirements analysis using the process of Concept Mapping [20]. Concept mapping is a process to describe ideas of an expert group of people on a given topic. Concept mapping process consists of: generation of statements by the experts (brainstorming); rating and sorting of statements; and interpretation of the concept map (data analysis). While all three stages may be done in face-to-face sessions, in this study the first two stages were done by mail due to participants' busy schedules and different locations. All concept mapping analyses were accomplished using The Concept System© (Version 4.0.147, Concept Systems Incorporated, Ithaca, NY). The results are represented as concept in a visual form that represents the focus of experts (see Fig. 2). We considered it a useful method for requirements analysis for developing a conceptual framework of Social Support System. By using the Concept Mapping process we intend to get group opinion of experts on the distinct features of SoSuSy.

On the basis of research problem we selected a total of 11 different participants from 7 different countries across different continents. Each participant came from a variety of educational backgrounds, namely: computer sciences, business management, human resources, education sciences and journalism. The idea was to gather varied expert opinion on the topic of Social Support System, from a diverse group of people. An email invite was sent to each of the participants with the brief description of the requirements of social support systems in Learning Network. They were asked to think-aloud about the need for such a system in Learning Network that searches for people. They were given a trigger statement: "*What defines a good Social Support System in Learning Network*". The trigger statement helped them to generate statements about the features or characteristics, that they thought are necessary to develop such a system in Learning Network. After each participant has completed the task of sorting, the results of all the participants are combined. First, a similarity matrix was constructed that represented the relative similarity of participants' sorting statements, i.e the results of the sort for each person are put into a square matrix which has as many rows and columns as there are statements. The values of this matrix is either '1' or '0'. The value '1' indicates that the statements for that row and column were placed by that person together in a pile while a '0' indicates that they were not. Second, the individual sort matrices were added together to obtain a combined group similarity matrix which is considered as the relational structure of the conceptual domain because it provides information about how the participants grouped the statements. A high value in group matrix indicates that many of the participants put that pair of statements together and implies that the statements are conceptually similar in some way. This group similarity matrix was analyzed using non-metric multidimensional scaling analysis with a two-dimensional solution, which generated x and y coordinates in a two-dimensional space for each statement based on its mathematical similarity to other statements. Third, statements were combined into clusters using a hierarchical cluster analysis. The results of the hierarchical cluster analysis were superimposed on the multidimensional scaling results to create a map displaying the points graphically within each group, with polygonal boundaries surrounding the points in each cluster group. A hierarchical cluster analysis yields all possible cluster solutions, from each statement in its own cluster to all statements in one cluster.

E. Results

In Fig. 2, there are 10 different clusters shown, which depicts how they were grouped together by hierarchical cluster analysis [20]. The main point of interpretation of the cluster map is that all participants come to figure out well the interrelationships among the clustered statements. It is aimed that everyone in the group has a clear picture of the project through the concept map. The clusters shown are depicting the expert opinion on various features that a Social Support System should have with varied degree of importance (shown as multiple layers on each cluster).

We briefly list and explain the meaning of each of the 10 clusters as depicted in Fig. 2.

1. Technical features: Focusing the state-of-art technologies for development like web 2.0 applications and Social apps.

2. Showing search similarity: The feature focuses on the search options where people would like to know the search results similar to what they are looking for.

3. Visibility: The feature focuses on the how social help system provides visibility of learners in the Learning Network.

4. Business application: The social help system as a tool for collaboration for further interests and commercial interests among people.

5. Communication among learners: The tool supports effective sharing of knowledge among learners facilitating communication via email, instant messengers or phones.

6. Learning community and connection among varied people: The tool supports forming learning communities and enhancing communication among the participants.

7. Facilitating learning and engagement: The tool provides support for bringing people to engage on a learning task and enhance learning by social engagement.

8. Interface design: Easy to use features and user-interface to search for suitable people in a network of learners.

9. Effects on society: The overall effects on society as a useful feature for supporting learning by socialization.

10. Output and Solution execution: The feature focusing on additional support like finding not only people but also relevant learning resources, supporting external collaboration, other embedded support.

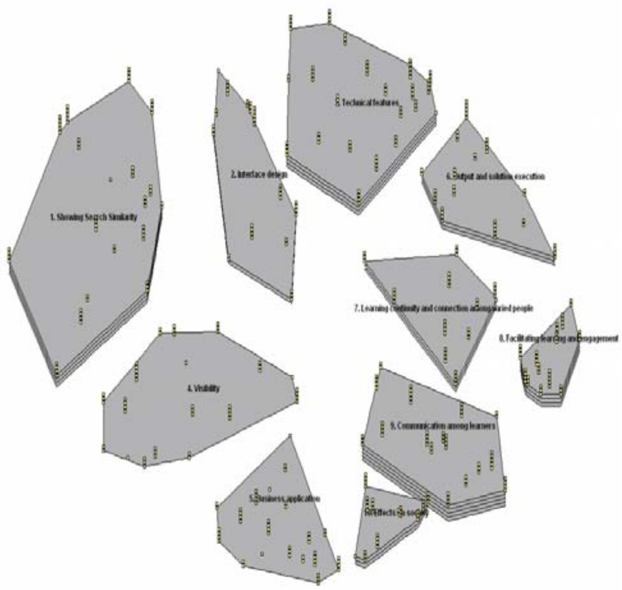

Figure 2. Cluster Map eliciting the focus on different required features of a social help system

IV. Discussion

Web 2.0 and Social Web provide the possibilities of exploiting the web to develop services for people recommendation in a Learning Network. The Social Support System plays the role of ‘knowledge broker’ to effectively moderate knowledge sharing between the members of a Learning Network. Social-support in the Learning Networks would give many benefits to a learner. First, the problem of isolation of learner in online Learning Network could be addressed by bringing a learner in contact with other learners. Second, a learner would not only depend on experts but s/he can seek help from any suitable person available in the heterogeneous Learning Networks. Third, it is possible that connecting people to other people, one can share and exchange expertise about the information which is not explicitly documented rather held by individuals, like peoples’ experiences, interests and also tacit knowledge. To the best of our knowledge we claim that the use of expert Concept Mapping method is a novel approach in needs analysis of Social Support System. We will report on further results in consecutive papers.

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Innovative Learning and Teaching Methodology in Electronic Technology Area

A Case of Study in Computer Science University Degrees

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Abstract—**This paper describes an experience that has been carried out by several professors in different subjects. Our experience is framed within the First Plan in Teaching of the University of Seville. All involved subjects belong to the electronic technology area and from three Computer Science degrees. We propose to use, in a combined way, some learning techniques: cooperative learning as complement to traditional learning, role-playing technique and jigsaw technique. We have considered a base methodology but in each subject a variant of it has been accomplished. We have used several evaluation techniques, such as reciprocal evaluation, electronic portfolio and check lists. Applying our methodology helps us to detect learning problems before the term ends. Also, in tune with the framework of the European Higher Education Area (EHEA), our methology gives a boost to develop transversal competences as important as work (or study) management, empathy and understanding of other members in a workgroup, conflict resolution, capacity to make decisions as well as coordinate and communicate with other members in a workgroup and also with the professor.**

Keywords-component; Innovative education, evaluation techniques, cooperative learning, role-playing, reciprocal evaluation, electronic portfolio.

I. INTRODUCTION. BACKGROUND

The experience described in this article is part of a project granted by the University of Seville's First Self-funded Teaching Scheme. This project focuses on aspects related to the implementation of the role-playing technique combined with cooperative work. The tasks carried out under this project seek improvement in the learning process of students.

The project has been implemented in all three Computer degrees at the University of Seville:

- Engineering in Computer Science (ECS, 5 years)
- Technical Engineering in Computer Systems (TECS, 3 years)
- Technical Engineering in Computer Management (TECM, 3 years)

The experience described in this article is a summary of what was implemented during the academic year 2008 / 2009 in classroom groups listed in TABLE I. The First-year courses are all compulsory, while the third and fifth-year subjects of study are optional.

TABLE I. SUBJECTS OF STUDY INVOLVED IN THE PROJECT

Subjects of study	Degree	Year	Class-room group	Nº of students	Teacher
Computer Structure and Technology II	TECM	*1º*	2	*87*	*M.C. Romero*
Computer Structure	TECS	*1º*	1, 2 and 3	*240*	*I.M. Gómez & M.P. Parra*
Computer Structure	ECS	*1º*	1 and 2	*150*	*C. Baena & M. Valencia*
Peripheral and Interfaces	TECS	*3º*	All	*120*	*F. Sivianes*
Advanced Digital Systems	ECS	*5º*	All	*20*	*M. Valencia*

The content of this paper is arranged as follows. In the next section we outline the motivations of our work. In section III we identify our main goals and, in section IV, the methodology followed for the execution of the work, which presents variations in the different subjects of study. In Section V, we discuss briefly some of the results obtained and, in section VI, we finish by stating the main conclusions.

II. MOTIVATIONS

Traditionally, expositive lectures have been the most common in university classrooms promoting, in most cases, individual student learning. With the implementation of the EHEA [4], the Technical College of Engineering and Computer Science at University of Seville joined in 2003 a pilot adaptation project, which, over time, has incorporated most of the subjects taught at the Technical College. Our department has actively participated in this pilot experience from the beginning and during subsequent courses, incorporating into their courses different ongoing evaluation mechanisms in line with the new European framework ([7], [8], [9] and [10]).

In our effort to improve student learning, during the last academic year (2007/2008) we started an isolated experience in group work and in the current academic year (2008/2009) we have implemented the project entitled "Implementation of the role-playing learning technique in groups from different computer science degrees and courses". Furthermore, in some of the groups, the role-playing technique was combined with cooperative learning activities.

In the role-playing technique or role exchange [7] students adopt a role and are encouraged to think, act and make decisions as their characters would. This technique promotes creativity, teamwork, reading and oral and written communication. This is a very versatile technique that can be applied in virtually all areas of knowledge and enables the simulation of real-life situations.

Moreover, as J. B. Cuseo noted in [3], cooperative work provides some advantages compared with traditional learning, such as:

- Promoting the active involvement of students during the learning process,
- Giving importance to the interaction of group members as a tool to increase the level of learning (group and individual),
- Reducing dropout rates in classrooms,
- Promoting critical thinking,
- Increasing student satisfaction in what they learn and how they learn it and promoting more positive attitudes towards the subject of study,
- Achieving better academic performance in science and technical areas, and
- Preparing students for the workplace.

In our project we propose to combine both techniques taking the best of each approach.

III. OBJETIVES

Our work focuses on improving the learning process of students studying subjects related to Electronic Technology within Computer Science, although what is described in this article could be applicable to any other matter. In this paper we propose its application to five subjects of study including:

- Computer Structure and Technology II (TECM), Computer Structure (TECS) and Computer Structure (ECS): all three are compulsory subjects for first year students and have very similar content. They are courses on computer design and applications –of Digital Systems in general– at RT (Register Transfer) level, and by creating a bridge between hardware and software, they develop programs at the machine-instruction level (assembly).
- Peripherals and Interfaces (TECS) is a third-year elective subject that aims to provide students with knowledge about specifications and technical literature on peripherals provided by manufacturers of equipment and programs; to solve problems with peripherals and interfaces found in an information system, application or network and to design and implement a control software or driver to control peripherals.
- Advanced Digital Systems (ECS) is a fifth-grade subject also optional that deals with the realization of digital systems with high speed and power consumption performance using advanced integration technologies and high-density programmable circuits (FPGA: Field Programmable Gate Arrays).

As mentioned before, in order to achieve this improvement in the learning process two different techniques have been jointly applied: role-playing and cooperative learning. They have not been applied exactly in the same way in all groups, as we will explain below.

On the one hand, by applying the role-playing technique we attempt to promote empathy and understanding for others, since all students perform all defined roles and are able to put themselves in their peers' shoes. Putting it into practice continuously during the academic year, students will be able to recognize, in themselves and in their peers, their capabilities, attitudes, values, and in some cases, to characterize their conduct and that of their classmates. In addition, it encourages students to accept others, resolving conflicts and developing responsible decision-making skills.

Furthermore, when combined with collaborative work, the development of abilities related to the five ingredients of cooperative learning is encourage [6]: positive interdependence, individual accountability, face to-face interaction among the peer group, interpersonal and group skills (such as coordination and communication) and group reflection.

All these abilities can be considered within the transversal skills put forth by the EHEA and its practice enables students to enter the workforce with some background in these skills.

As we will see below, in some classroom groups the ultimate goal has been for each cooperative group to develop, by the end of the teaching period, an electronic portfolio that showcases the work developed by that group during the entire course and, moreover, it has proved a useful tool for evaluating the work of the group.

IV. Methodology

First of all, it must be noted that the activities developed for this project were proposed to students as elective tasks as part of continuous assessment. Then, at the beginning of the term, students will decide whether or not they want to perform them. At this point an immediate question arises: what do students who choose not to perform these tasks do when group sharing takes place in the classroom? In our case, that time may be used to study the subject or resolve any question that the teacher can propose.

If the student chooses to perform these activities, we ask them to make certain commitments, such as continuing with the activities throughout the semester, otherwise he or she would leave the group stranded, and attending classroom lessons, at least on the days scheduled for group sharing (they are provided with a calendar).

To carry out this project each teacher divided the subject to teach in as many sections as the different tasks programmed in the course. Obviously, the division of the subject depends on the subject syllabus and how the teacher wants to schedule each activity during the semester. In our case, although the basis of the methodology was common, each teacher applied it slightly differently in each subject, which shows that, albeit general, this methodology can be tailored in multiple cases. A detailed explanation on what has been applied in each course will be provided in the next sections.

A. Methodology basis

Students are assigned to three- or four-member base groups[1], ensuring that the number of students matches the number of roles defined. The number of roles should match the number of sections in which the teacher has decided to divide the subject syllabus for the continuous assessment. Thus, each student performs all the roles on a rotating basis and the total number of activities carried out by the group also matches that number.

Several strategies are possible for the selection of base groups. For example, in one of the strategies applied in our case students can choose a partner and the teacher is the one who arranges the entire group in pairs. In this way, the formation of groups of friends is avoided and it promotes students to strive to work with peers whom they do not know, which is a situation similar to the one they will most likely face as they enter the workplace.

Each group should do as many activities as the number of sections in which the teacher has divided the subject syllabus and each student has a different role in each task.

The activity statement of each cooperative task performed by the groups is made public through the e-learning platform (WebCT in our case) or in the classroom. It includes all the roles and their descriptions. Each group member may decide the initial role assignment.

[1] Base groups last for the entire course.

In some courses, each group should develop an electronic portfolio which will include the work of each section, both the individual work of each group member and that of the group. Portfolios are handed in upon completion of each section of a task, so that teachers can analyze learning trends and detect any anomalies, which is what teachers usually call “concept failures”. Error explanations are provided to the group, not to individual students, so if it is a common error, not only will the student who made the mistake learn, but also the rest of his or her teammates.

In the prototype project each task is also divided into four parts:

- Part I: Work Planning. Each group should come to an agreement and establish a task calendar. When the activity is finished, each group should hand in a document showing the originally planned programming and the real one, with a brief analysis explaining the difference between them, either in a paper document or uploading the document to the electronic portfolio.
- Part II: Assimilation of fundamental concepts. For this part the following must be programmed:
  - Individual reading of the relevant subject outside the classroom and each group member will independently develop:
    - Student 1: a concept map relating the key concept of the relevant subject to all areas studied in this subject.
    - Student 2: ten three-choice, multiple-choice questions (a, b and c) on the appropriate topic.
    - Student 3: a glossary of the fifteen key terms of the relevant subject.
    - Student 4: A two-page (maximum) summary of the most important aspects of the topic.
  - Experts meeting to discuss the documentation produced using the puzzle technique (or jigsaw) [5].
  - Base group meeting so each student can explain his/her assignment to their classmates.
  - Homework: corrections, amendments and assignments should be included in the portfolio or paper document.
  - Submission of portfolio or paper document to the teacher.

  The idea is that students learn to solve any problems and questions proposed by the teacher on the subject to study, using the puzzle method, and that any group member understands how the concept map is constructed, is capable of solving the multiple choice questions, defines any glossary term and considers whether the summary of the subject prepared by their colleague is adequate or not.
- Part III: Practical applications of concepts. Learning to select the most important aspects of the subject, to write a statement correctly and to solve it in the most appropriate way.

TABLE II. *ROLE ASSIGNMENT*

Student	Role	Developed Skills
Student 1	PROPOSER Teacher that proposes a test statement on the relevant matter.	The ability to analyze what information is the most important of the subject taught; the ability to effectively search for information to prepare the statement; implementation of the knowledge acquired in Part II, since the statement should be feasible for the Student; self-assessment capability; and motivation to propose innovative and challenging statements.
Student 2	REVISER and EDITOR Teacher that: • reviews the proposed statement • corrects the exams • reviews exams with students once they are corrected	Critical ability, and putting into practice the knowledge acquired in Part II. The ability to assess the work done by someone else and to take responsibility for that assessment. The ability to set objective correctness criteria. Developing communication skills when justifying grades to students during the review period with the marking criteria set in advance.
Student 3 (*)	STUDENT Student tested on solving this statement in the time specified by the proposer.	The ability to cope with a problem on your own in a bounded time and the motivation to reinforce the knowledge acquired in class and the work of Part II.
Student 4 (*) (**)	STUDENT Student tested on solving this statement in the time specified by the proposer.	The ability to cope with a problem on your own in a bounded time and the motivation to reinforce the knowledge acquired in class and the work of Part II.

(*) Students 3 and 4 should resolve the problem individually.
(**) When four-member groups are not feasible, the Student 4 role disappears.

Table II shows the initial role assignment, taking turns with each activity, and the various skills that are developed for each one.

After this phase, each student must prepare the documentation for the group work associated with their role. The documentation of the entire group is included in the portfolio or in a paper document and delivered to the teacher for review.

- Part IV - Mini-conference: Learning to apply the skill of synthesis, to perform oral presentations and prepare visual documentation in the shape of a poster.

The group should prepare a poster on the practical application of Part III and give a five-minute oral presentation using the poster. The teacher in-situ will choose who will perform the presentation, thereby evaluating the whole group. When using the electronic portfolio for assessment, the poster will be included in the same electronic format.

B. Variations in the different subjects

The information related to the implementation of the project to each of the subjects involved is shown in TABLE III and TABLE IV.

TABLE III. *SUMMARY OF THE METHODOLOGY APPLIED IN ALL THE SUBJECTS INVOLVED IN THE PROJECT (I)*

Subject to study	**Total no. of tasks during the course (***)**	**Topics addressed**	**Pedagogical techniques applied**	**Evaluation**
CST2(TECM) – Group 2	4	– Analysis and Design of Digital Systems – Design of a simple computer – Semiconductor memory – Case study: the MC68000 microprocessor	– Role-playing – Cooperative Work – Puzzle Technique (jigsaw) Parts of the base project: All	Two individual partial tests, with two parts each, corresponding to the division of the syllabus, scored from 0 to 10. In addition, students can earn up to 1 extra point for the cooperative work by applying: - the self/peer evaluation using rubrics, - the concept map evaluation - the evaluation the poster oral presentation, - The portfolio evaluation. This additional point is added to the average score of the partial-test.
CS (TECS) – Group 1	3	– Analysis and Design – of Digital Systems – Design of a simple computer – Case study: the MC68000 microprocessor	Role-playing Parts of the base project: - Part III	1 extra-point maximum will be added to the final score of the partial test.
CS (TECS) – Group 2	3	– Analysis and Design of Digital Systems – Design of a simple computer – Case study: the MC68000 microprocessor	Role-playing Parts of the base project: - Part III	A total of one extra point will be added to the final score of the partial test.
CS (TECS) – Group 3	4	– Analysis and Design of Digital Systems – Design of a simple computer – Case study: the MC68000 microprocessor	Role-playing Parts of the base project: - Part III	A total of one extra point will be added to the score obtained in continuous assessment, which consists of two tests: **Test 1:** the SD-DC assignments score will be added. **Test 2:** the 68000 assignments score will be added.
CS (II) – Group 1	1	– Design of a simple computer	Role-playing Parts of the base project: – Part I – Part II – Part III	A total of two extra points will be added to the (CS) test score. This test will carry 33% weightage on the final score, so this assignment is worth 0.67 points.
CS (II) – Group 2	1	– Design of a simple computer	Role-playing Parts of the base project: – Part I – Part II – Part III	A total of two extra points will be added to the (CS) test score. This test will carry 33% weightage on the final score, so this assignment is worth 0.67 points.

TABLE IV. *SUMMARY OF THE METHODOLOGY APPLIED IN ALL THE SUBJECTS INVOLVED IN THE PROJECT (II)*

Subject to study	Total no. of tasks during the course (***)	Topics addressed	Pedagogical techniques applied	Evaluation
PI	3	– Characterization of peripherals and interfaces – Starting the development environment. – Driver implementation for peripheral control through its interface	Role-playing	Two individual partial tests, with two parts each, corresponding to the division of the syllabus, scored from 0 to 10. The work group students who, after the individualized assessment of the assignments, pass the tests, need not sit the partial tests to pass the course.
			Parts of the base project: – Part I – Part II – Part III – Personalized assessment on the work done	
ADS	3	– Temporal characterization – Arithmetic circuits – Synchronization	– Role-playing – Debates	It will account for 25% of the final mark of the continuous assessment. 25% for theoretical tests, and 50% lab project assignment.
			Parts of the base project: – Part I – Part II – Part III	

TABLE V. *QUANTITATIVE RESULTS FOR THE INVOLVED SUBJECTS*

Subject	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CST2 (TECM) Group 2	87	4/3	46	29	8	25	5	4	3
SC (TECS) Group 1	69	3	8 (partial 1) 4 (partial 2)	5(partial1) 3 (partial 2)	15(partial 1) 9 (partial 2)	3(partial 1) 2 (partial 2)	10 (partial 1) 4 (partial 2)	2 (partial 1) 1 (partial 2)	5 (partial 1) 5 (partial 2)
SC (TECS) Group 2	67	3	14 (partial 1) 5 (partial 2)	9(partial1) 5(partial 2)	12(partial 1) 3 (partial 2)	4(partial 1) 2 (partial 2)	4 (partial 1) 1 (partial 2)	5 (partial 1) 3 (partial 2)	8 (partial 1) 2 (partial 2)
SC (TECS) Group 3	85	3	10	9	13	6	8	3	5
CS (ECS) Group 1	58	3/4	7	7	18	7	14	0	4
CS (ECS) Group 2	41	3	15	14	10	13	9	1	1
PI	94	4	64	2	25	60	16	0	7
ADS	12	3	3	3	0	3	0	0	0

(1) Number of students enrolled
(2) Number of students per workgroup
(3) Number of students who did assignments
(4) Number of students who took a test and did their assignments
(5) Number of students who took a test and did NOT do their assignments
(6) Number of students who passed and did their assignments
(7) Number of students who passed and did NOT do their assignments
(8) Number of students who failed and did their assignments
(9) Number of students who failed and did NOT do their assignments

V. RESULTS

By analyzing the number of students who took a test and did their assignments (column 4 at TABLE V) and the number of students who passed and did their assignments (column 6 at TABLE V), we can get that, on average, 80% of students who use this methodology pass the subject in continuous assessment or in term-end examinations.

On the contrary, if we analyze the number of students who took a test and did NOT do their assignments (column 5 at TABLE V) and the number of students who passed and did NOT do their assignments (column 7 at TABLE V) we observe that, on average, among the students who took the test but did not use this methodology, 54% failed.

We see that there is a significant deviation in the number of students who use this methodology in the different subjects and groups. We believe that this difference may be due to several reasons:

- In some subjects the methodology has not been implemented from the beginning of the semester, therefore there is no continuity in the implementation of these methods and their execution is late, when the student has already lost motivation in the subject.
- In some subjects a partial application of the methodology has been carried out (only Role-playing - Part III - is applied, but not the rest) and, curiously enough, the "passed" percentages obtained are lower (67%, 40 % and 67% for TECS groups 1, 2 and 3, respectively, and 86%, 100%, 93%, 93%, 100% for CST group 2, CS groups 1 and 2, the IP group and ADS group, respectively).

We must also take into account some peculiarities:

- In CS (II), each base group faced all three roles simultaneously: each group with respect to their peers had to assume the role of the teacher, reviser-editor and student.
- In CS (II), participation was planned for the third lesson of the term, which is evaluated in Test 2 of the three the subject has. At this stage of the term, dropping the course reached the usual high percentage in the last four academic years.
- In CS (II) group 1, the apparent "complete success" in terms of participants is due, at least in part, to the fact that the percentage of volunteers was low and the participants were the best students (those who excel in any system).
- In ADS the 3 participating students represented the total number of students in the course. The other 9 enrolled students never attended class or submitted any assignment.

VI. Conclusions

From an educational point of view, the implementation of this educational initiative has entailed:

- The study and experimentation with methodologies whose application is not usual in the courses taught.
- The carrying out of a methodological change aimed at learning and assessing the transversal skills that complement the assimilation of course content. The methodology allows to further assess subject-specific skills.
- Promoting the use of active learning methodologies.
- The analysis and promotion of different ways of group work.
- The design of practical teaching activities.
- The design and implementation of new assessment systems.

Having implemented this methodology, we can state that:

- It is undeniable that in carrying out this experience time and effort was spent to organize the activities, coordinate the work groups and review the students' ongoing assignments, which is added to the regular teaching activity. However, the following positive aspects can be noted:
  - Easy and quick detection of weaknesses in the (individual or collective) learning of subjects so that special attention can be paid to them in classroom lessons.
  - Students become more involved in the subject, know and treat their classmates with more familiarity, and classes are more interactive, which will have positive implications in the learning experience.
  - In general, by using these techniques, students' grades are higher than they usually are, provided they are applied throughout the course and in a continuous fashion. For example, for CST(2) group 2 the percentage of students who passed the course in the first-term exam for the academic year 2007/2008 was 33%, while that of the academic year 2008/2009 was 70%.
- The main difficulties encountered were:
  - The high number of students. The courses involved in the project have an average of 77 officially enrolled students per class. Although the dropout rate is high, even from the beginning of the course, an average of 55 students often remain in class. So, in some cases, as we have seen, it involves a large number of working groups per teacher. With such a number of students / groups, we find that:
    - Group management is complex, especially during the first three weeks of the course. It is understood that it is just a matter of experience in the application of these techniques.
    - The application of the puzzle technique in the classroom is difficult for two reasons: first, the teacher cannot cope with the monitoring of the progress of the expert meetings and, secondly, the activity is very noisy. The first problem could be solved through the collaboration of student interns to assist in managing the work of groups during the group sharing sessions, and the second disadvantage begins to disappear as students become accustomed to this way of working.
    - Narrowing which parts of the syllabus can be set aside for cooperative activities and which parts are not is a complex task. The content of these courses is dense and it is not trivial to discern what is accessory.
- Explaining the new method. The teacher must devote classroom time to explain how the new method works and what the procedure to be followed by students is. That time is subtracted from the teaching of the subject,

but we think it is not wasted time because the student's achieved understanding of the material is deeper.

- First-year students are more confused by the many changes, so we consider it more appropriate to apply these techniques in second term subjects.

Finally, note that some of the factors used for assessment (and rating) of each student in each base group were:

- Rule compliance: deadlines, submission of reports and maintaining base group meetings.
- The information provided by students: time spent, resources used, interaction with other group members, group self-assessment and co-assessment among members of the same base group (through the use of headings, for example).
- The teacher's grade on the assignments produced and students' tasks directly supervised by the teacher.

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An Experience in Cooperative Learning Developing a Real Aerospacial Project

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***Abstract* — A lot of training time is devoted to help teachers arrange appropriate interactions between students and materials, and to how teachers should interact with students. However, how students should interact with each other is relatively ignored. It is a good idea that students learn within a supportive community in order to feel safe enough to take risks. Cooperative Learning (CL) is a successful teaching strategy in which small teams, composed by students with different skills, use a variety of learning activities to improve their understanding of a subject [1]. Each member of a team is responsible not only for learning what is taught but also for helping his or her teammates learn, thus creating an atmosphere of achievement. In this paper an experience in CL with a group of students with different skills and ages developing the harness subsystem of the first lunar spacecraft built and operated by students across European Space Agency (ESA) Member States and ESA Cooperating States is described.**

Keywords- Cooperative Learning, aeorospace project, European Space Agency.

I. INTRODUCTION

The European Student Moon Orbiter (ESMO) is planned to be the first European student mission to fly to the Moon [2]. ESMO represents a unique and inspirational opportunity for university students. ESMO provides students with valuable and challenging hands-on space project experience in order to fully prepare a well qualified workforce for future ESA missions, particularly those planned by the Exploration and Science programmes in the next decades.

In addition, ESMO has a powerful education outreach aspect and a strong attraction for younger students studying in universities across Europe. It also represents an opportunity to contribute to the scientific knowledge and future exploration of the Moon by returning new data and testing new technologies.

More than 300 students from 29 Universities in 12 countries are participating in the project, which has successfully completed its *"Phase A: Feasibility Study"* and it is proceeding into preliminary design activities *(Phase B)*. The ESMO spacecraft is designed to be launched into Geostationary Transfer Orbit (GTO) as a secondary payload in the 2013/2014 timeframe. The student teams are expected to provide most of the spacecraft subsystems, payload and ground support systems in coordination with their universities and through sponsorship by the European space industry.

The Power Supply Systems group, which is part of the Electronic Technology Division of the University of Oviedo (Spain), submitted a letter of interest to the ESA for participating in the selection process to find a university team to develop the harness subsystem. The proposal of this group was selected, after being evaluated for experts, and now the Power Supply Systems group is the responsible team of the harness subsystem of the satellite.

The Power Supply Systems group is formed by eight researchers, four of whom are PhD Electrical Engineers and professors, and the rest are PhD students. To develop the harness subsystem of the spacecraft, the group considered to form a team with engineering students and to implement some CL strategies. This kind of learning is still uncommon in technical areas of knowledge, but it is considered a key element for improving the capabilities of students [3]-[7]. Some university students with different skills were interested in ESMO and the team was composed in February 2008.

II. METHOD

A. ESMO groups and tools for cooperative working

The ESMO project is divided by the ESA in more than twenty subsystems, which include the whole spacecraft, and other necessary tasks as the ground segment or the mission analysis. Each subsystem is developed by a group of students who belong to a European University. These groups must interact with each other so that they know about the evolution of the project. To facilitate this interaction, the ESA encourages the use of some interactive tools. The most interesting ones are:

- A Google group, in which all subsystems are signed up, to discuss and comment about critical questions. Thanks to this tool all the members of the ESMO can know each other.

- A weekly chat, in which some questions are solved talking with experts and another problems are discovered thanks to the interaction between subsystems. It is a direct way to solve problems quickly in a real time conversation with the members of the rest of subsystems.

- A biweekly work report to evaluate the progress of each subsystem. It is a good way to teach students how to write and read technical documents.

- A FTP site for each subsystem to share some of their work with the other subsystems. This is a very useful tool to be updated of all the progress of the different subsystems.

- On-line interactive programs to develop some of the work using dedicated software provided by the ESA. Students have to adapt themselves to use dedicated programs for each activity.

- Four workshops per year at European Space Research and Technology Centre (ESTEC), where one representative from each team is invited. This is the moment when all the students can talk together. They have to present their works in public, ask other members some questions, speak with experts of the ESA, etc. Usually in these workshops there are also some activities to have fun all together.

Thanks to all this tools the members of each subsystem have a global view of the evolution of the project. The interaction between students from different countries, cultures, universities, and degrees also help them to develop communication and social skills.

B. Structure of the Harness team.

The actual structure of the Harness team, defined by the Power Supply Systems group, can be seen in Figure 1 and it is described as follows.

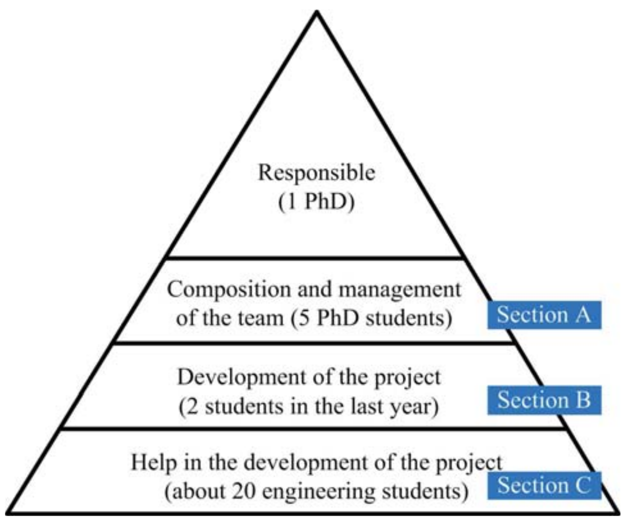

Figure 1. Structure of the Harness team

The responsible of the Harness team is the responsible of the Power Supply Systems group, an expert Electrical Engineer PhD professor, who can help the rest of the team to solve important problems. He is not the responsible of the organization of the Harness team, he only advise the other components of the Power Supply Systems group if they have great troubles.

The rest of the components of the Power Supply Systems group, particularly five of them (all of them are PhD students), have composed the Harness team and must manage and organize its work. They have to evaluate all the advances made by the students, solve the questions they could have, distribute and organize the work, etc. These members of the Harness team are expected to participate in the project till the launching of the spacecraft. We are going to call them, section A students.

Regarding the development of the harness of the ESMO project two engineering students are making their Master thesis. They are working together, making reports, schemes of all the system and the connections needed, revising the electrical requirements of the rest of the subsystems, etc. These two students are making most of the jobs required in the design of the harness, supervised initially by section A students and latter by experts from the ESA. We are going to call them, section B students.

The Harness team is completed with a group of engineering students (about twenty) with different ages, skills and knowledge. These students do not have any benefits for participating in this project (such as money, increase in their marks, etc) except for their own learning about aerospacial projects. These students are divided in small groups to analyze each subsystem. They help students section B, and at the same time they are learning about the global system and the harness subsystem. We are going to call them, section C students.

The different degrees of students forming the Harness team are specified in Table I. As can be seen, most of the students are telecommunications engineers, simply because some members of the Power Supply Systems group are teachers in this degree and they are very well know by the students.

TABLE I. DEGREES OF THE MEMBERS OF THE HARNESS TEAM.

	Number	Electrical Engineer	Telecommunications Engineer
Responsible	1	1	
Management	5	2	3
Development	2		2
Help and assistance	20	2	18

Until this moment, we have been working with this structure for approximately seventeen months with very good results. Nevertheless, variations on the student number and possible evolutions between different student sections are expected.

After being working with this structure for a time, we can recommend a range of students in each section: section A students must be between 3 and 6 to properly manage all the rest of students. Section B students must be between 1 and 3 to carry out most of the required jobs. Finally, section C students must be between 15 and 30 students to help students B. We are very proud of the great number of students who want to participate in the project and their motivation, and so we can choose the number of students in each section.

C. Cooperative tools and work

About thirty students from different degrees and obviously with different skills, as it has been mentioned before, compose the Harness team. This is a very important advantage to develop an interdisciplinary topic as the harness of a satellite.

Nevertheless, it is difficult to coordinate so many students. Several cooperative tools have been used to make easier the interaction between all the members of the team. The most important ones are:

- Biweekly meetings: these meetings are being mostly carried out by section B students, with oral presentations supported with PowerPoint slides, in which their advances are presented and discussed with the rest of students. Occasionally, section C students make some oral presentation presenting important changes in other subsystems.

- A Google group: section C students have created a Google group (different from the one of the ESA), as can be seen in Figure 2, in which all the members of the team are signed up. We can interact and express our opinions about each subsystem of the satellite and the questions discussed during the biweekly meetings.

- An electronic calendar: thanks to this tool, integrated in the Google group, the meetings can be programmed in an adequate date for most of the members of the team. It is difficult to find a satisfactory date for all the students, due to their different timetables. Usually, meetings are programmed in some particular hours in the week, that are specially good for the students, then the members of the team can confirm their attendance, and after evaluating the number of confirmed members, the date is postponed or fixed. This can be easily done using the Google group.

Figure 2. Google Group of the Harness team

- Webpage: A couple of section C students have elaborated a webpage of the team. This webpage is updated monthly with the most important advances made by the team. Thanks to this tool other students can know about this project and can be interested in participating. On the other hand, this webpage adds our sponsorships and publishes the help of some people and institutions. You can see this webpage in the following address http://pels.edv.uniovi.es/ESMO/

Figure 3. Presentation of the webpage

III. Results and discussion. Meeting of goals

A. General learning of different section of students.

Most of the members of the Power Supply Systems group, whose structure has been mentioned before, besides working as teachers in a university are investigating in several projects. The available amount of time to carry out the ESMO project was very little. Nevertheless, the project seemed so interesting that they wanted to participate developing one of the free subsystem, in particular the harness subsystem. As they could not leave their projects, they thought about forming a group of students, with a particular structure, to carry out this new and interesting project. Initially, section A students (PhD students) were very pessimistic about the participation and collaboration of the rest of degree students, but when the announcement of the project was published a lot of students were interested and so, the Harness team was created.

Using the mentioned CL tools, the needed jobs for the harness subsystem in the ESMO project has been properly performed till this moment without too much time expended by section A students. Moreover, these members have put into practice their knowledge about CL, and have learnt about the interaction between students and between teachers and students. Their principle objective was to motivate the rest of students and give them enough tools to work together. They have not developed the harness of the ESMO but they have helped the degree students (especially from section B) to do it.

The two current section B students have carried out an excellent work which can be enough to present as a Master thesis, however they will continue working in the team (their Master thesis will be presented in December 2009). They have elaborated most of the documents needed, asking some questions to the rest of the students about the rest of the subsystems in the biweekly meetings. These two students have developed three different possible solutions for the harness of the satellite, which were presented in the last workshop in the ESA with a lot of success.

Section C Students have helped these two colleagues and have improved their knowledge about global and interdisciplinary projects in general and the ESMO project in particular. Most of these students have an important global knowledge of the whole spacecraft, which few of the rest of the participants in the ESMO project have.

In the following months section B students are going to present their Master thesis, and as they are going to finish their degree, a section C student is going to start elaborating another different Master thesis. All the students of the team have been assisting to most of the meetings, so they are well updated about the progress of the project (also thanks to the news in the Google group). As all of them have a lot of knowledge about the project, they can progress forming part of a higher section of students in the proposed structure of the team.

B. Technical proposal to the harness subsystem.

It is nearly impossible to sum up in this paper all the details of the technical solutions provided by the two section B students to the harness subsystem. However, an introduction to the solutions provided by the team for the harness of the ESMO will be given.

The most important requirements for all the components of the harness (cables, connectors, couplers, etc.) are:

- All cables shall be insulated with modified radiation cross-linked PTFE.

- All connectors contacts shall be Gold-Plated (Be-Cu) and crimpable.

- All components shall have Space Qualification

It is also very important the distribution of the harness in the spacecraft, taking into account the allocation of the rest of the subsystems (Figure 4).

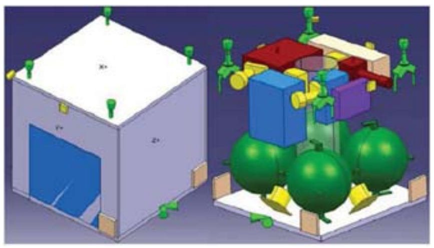

Figure 4. General structure of the ESMO

In ESMO satellite it can be differentiated the following four types of harness:

1. Harness of Power: The Electrical Power Subsystem (EPS) provides a 28V unregulated bus. The connectors considered are rectangular. In the EPS box there will be 4 connectors with 37-pin and in the rest of subsystems a 9-pin connector is enough, except in critical subsystems where redundant connectors are needed (Figure 5). The cable shall be twisted pair and is estimated to be 24AWG for most subsystems.

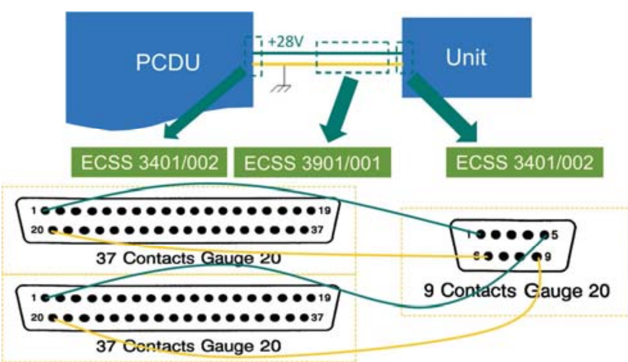

Figure 5. Distribution of the pins of the harness of power

2. Harness of CAN: The design of the CAN network is about to be defined by a proposal from ESA-ECSS (European Cooperation on Space Standardization). The connectors shall be compliant to specification: MIL-C D38999 and shall be a 9-pin micro-miniature D-type. The cable is recommended to be Electromagnetic Pulse (EMP) shielded. This option uses only two connectors per CAN node, both with the following pin-assignment (Table II):

TABLE II. DISTRIBUTION OF THE PINS OF CONNECTORS IN CAN BUS.

Pin	Function	Pin	Function
1	CAN_H (PRIMARY)	6	CAN_L (PRIMARY)
2	Reserved	7	CAN Ground (Required)
3	CAN_SHLD	8	CAN Ground (Optional)
4	Reserved	9	CAN_L (REDUNDANT)
5	CAN_H (REDUNDANT)		

3. Harness of RF: The RF connection works at 2.3GHz. There are four connections between the transceiver and the antennas. The considered cable is Coaxial with less than *0.5dB/m* losses. For this purpose, SMA connectors (Military Qualified) are required in order to satisfy the requirements of total transmission losses.

4. Harness of RS-232 & RS-422: These connections are conceived as dedicated lines between the most critical subsystems of the spacecraft. Both protocols have a common physical layer and use the same connector and cable type. These connections will be designed in accordance with the respective standard, but taking into account the general requirements written above.

C. Learning of the members of the team.

Obviously, all the members of the team have obtained some technical knowledge about the project (depending on its section and the participation in the team) which is considered very important. This learning has been demonstrated by all the students in the meetings of the team with oral presentations, clever questions, great suggested ideas, etc. Most of them have learnt some of the following topics:

- Selection of components (connectors, cables, couplers, etc) following the requirements for aerospacial missions.

- Knowledge about the different kind of electromagnetic interferences that can affect the components in the space and some ways to avoid this effect.

- CAN bus networks specially develop to use in the space.

- Different kinds of redundancy used in the harness for aerospacial validation of the system.

- Use of dedicated software (DOORS) to learn how to analyze electrical requirements taking into account the specifications of the system.

- Use of dedicated software (CATIA) to develop the 3-D design of the harness of the system

- Different solutions to manufacture an electrical ground to use as the reference (this is not so obvious in a spacecraft).

They have also improved some transversals competencies such as search of information, capacity of synthesis, critical thinking, decision-making and read and write technical documents in a different language.

Also, in order to analyze other general benefits of the participation in the Harness team, we have evaluated most of the students making oral presentations. We have compared the results of the evaluation of the students participating in the

ESMO project with other students making their Master thesis in different topics, not related with the ESMO.

In Figure 6 some results are showed, where we can see that students participating in the ESMO project obtained slightly better results than the other students. We should take into account that students making their Master thesis are in their last year, next to finish their degrees, while most of the students of the Harness team are in the third or fourth course of their degrees. These results demonstrate that students participating in the ESMO project have a great level of motivation and participation, working very hard in their oral presentations without any reward.

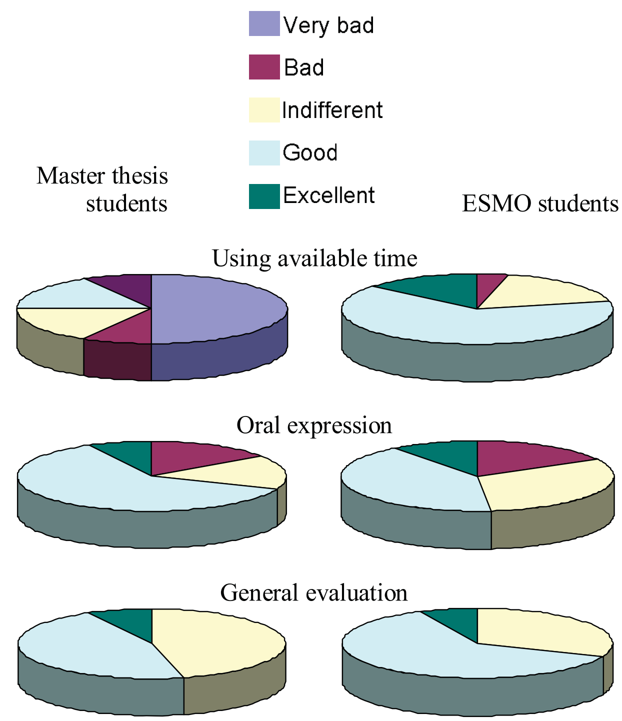

Figure 6. Evaluation of the oral presentation of the team

D. Evaluation of the progress of the team.

To evaluate the progress of the project a little opinion poll was developed to all the members of the Harness team (section A, B and C students). All of them estimate their activity in the team and the benefits in their learning of the participation in the project. The answers of different sections of students are significantly different, due to their different task developed in the team, however all the responses have been put together to evaluate the progress of the team in global.

In Figure 7, the results of the survey are showed. The project is well valued for almost all the members of the team. However some members feel that their activity in the team is very poor, especially section C students. To solve this problem we are right now carrying out different free task for this kind of students, such as oral presentations, search for sponsors, etc.

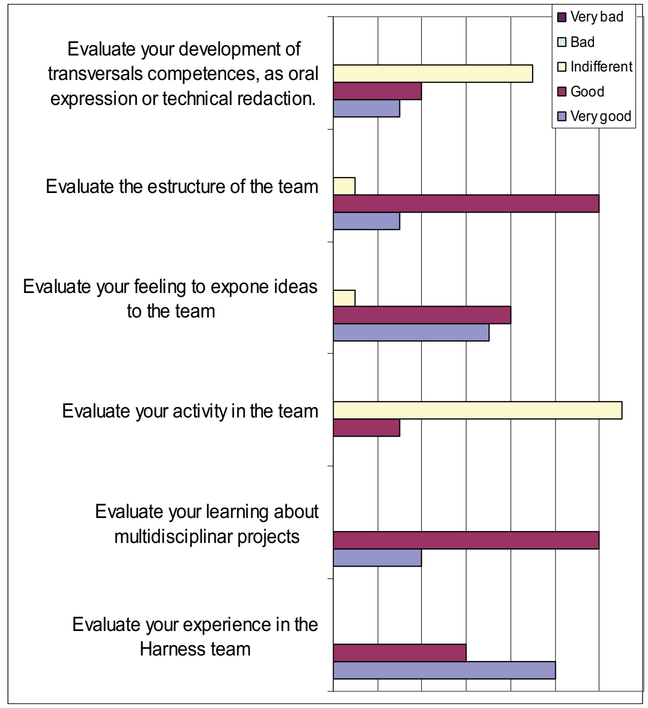

Figure 7. Evaluation of the project by the Harness team

IV. CONCLUSIONS

The possibility of being involved in a very interesting project working in aerospace topics in the ESA, like the ESMO project, was proposed to a group of researchers with very little time to work on it. In spite of this constraint, the project was so attractive that they considered trying to develop it with the help of some students. The interest of so many students for this project was surprising and aims the researchers to form a team to carry out the harness subsystem of the ESMO project.

Thanks to the help of the students the time expended by the researchers would be less, but the main problem would be how to organize and manage so many different kinds of students.

The researchers of the Power Supply Systems group decided that the project should not be developed by them and then explain the work made to the rest of students. This could be similar to the traditional way of teaching, which can be compared to a train that will go on, with or without their wagons.

On the other hand, the proposed methodology was to let the students make all the work required to carry out the project. The task of section A students would be the distribution of the work between the different kinds of students and provide suggestions, revisions and help in certain mishaps. This method is similar to the proposed way of learning by the European Higher Education Area (EHEA), which can be compared to a racing shell that will only go on if everyone row, and so the working rate will be specified by the own students [8].

Figure 8. Metaphor between teaching (train) and learning (racing shell).

Putting into practice the CL tools and methodologies that have been described in this article, some very interesting solutions have been proposed to develop the harness of the ESMO. The learning of all the members of the Harness team has been very successful without having to expend a lot of time. Different students have learnt different concepts about harness, the other subsystems (communications, propulsions, power conversion …), interdisciplinary projects, cooperative and collaborative working, and besides that, they have shared with each other the different knowledge they have. Moreover, they have improved a great number of transversals skills.

All the members of the Power Supply Systems group have been pleasantly surprised with the collaboration of so many students in the described project without any reward except from the learning of new topics. Moreover, the structure of students proposed and the collaboration between all of them using the CL tools detailed in this article, are considered to give very good results when developing a complex system as the harness of a satellite.

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Session 06D ICOPER Special Session: Assessing Assessment Formats - ICOPER Network

Assessing Assessment Formats: The Current Picture

Crespo, Raquel; Delgado-Kloos, Carlos; Gutiérrez-Rojas, Israel
University Carlos III of Madrid (Spain)

Aligning Assessment with Learning Outcomes in Outcome-based Education

Crespo, Raquel; Delgado-Kloos, Carlos; Derntl, Michael; Gutiérrez-Rojas, Israel; Leony, Derick; Najjar, Jad; Neumann, Susanne; Oberhuemer, Petra; Simon, Bernd; Totschnig, Michael

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Current Issues With Assessment Formats and Interoperability

Agea, Álvaro; Delgado-Kloos, Carlos; Pardo, Abelardo
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Interoperable Content for Performance in a Competency-driven Society: Results from the iCoper project

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Assessing Assessment Formats: The Current Picture

Special Session: Assessing Assessment Formats

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Abstract— **Student assessment plays a fundamental part in every e-learning process, where it can serve to check whether the learner has achieved the intended learning outcomes (summative assessment), but also as a means to aid in the learning itself (formative assessment). Nevertheless, there exist no formal standards to cover this type of content, just some specifications, such as IMS QTI. In this article, we present a study of formats for assessment and their usage in Europe. We also present a reference metamodel for assessment that covers the needs of all stakeholders in relation to this topic.**

Keywords - assessment formats, IMS QTI, reference metamodel, ICOPER.

I. Introduction

ICOPER [1] is a Best Practice Network that started in September 2008, funded by eContentPlus programme of the European Comission. As part of the ICOPER objectives, a reference model (ICOPER Reference Model) will be provided and some mechanisms to ensure involvement, cooperation and adoption of standards in the European educational framework. To accomplish this goal, the project will systematically analyse the specifications and standards available and in use, to draw conclusions on their validity.

In the context of the ICOPER project, an effort is under way to analyse assessment standards and specifications. This work has been carried out by the work package "Assessment and evaluation testbed", led by Carlos III University of Madrid. The analysis has focused on IMS Question and Test Interoperability (QTI) [2] because it is considered as *de facto* standard. Besides, this work package has other responsibilities like proposing a set of best practices in the scope of learning assessment, detecting and solving QTI interoperability problems by helping to complete the available tools to guarantee a robust exchange of assessment material [3].

This paper presents the results of the analysis of assessment formats and specifications, from the technical point of view, and their actual usage in Europe. As a result of this analysis, a reference metamodel for assessment content is proposed as a best practice in the assessment domain.

II. Assessment formats and specifications

A. Methodology

The Model Driven Architecture (MDA) standard [4] has been used in order to analyse assessment specifications. Concretely, UML diagrams (what henceforth are called metamodels) have been used because they provide us with the following advantages as stated in [5]:

- Abstraction from secondary aspects such as syntax and concrete XML bindings.
- Better understanding of the format management.
- Development of systems easy to maintain and re-use (and therefore interoperable).

The criteria applied for the selection of the formats and specifications to be analysed are based on their relevance in the e-learning environment. Some additional formats used by ICOPER partners have also been included in the analysis due to their widespread deployment and experience as well as the possibility of an in-depth analysis of them granted by the consortium. The chosen specifications can be classified in two categories:

- **Assessment purpose formats**, whose main objective is the authoring of assessment resources. In this category, the studied formats are: IMS QTI (versions 1.2.1 and 2.1); formats belonging to Learning Management Systems (LMS), either open source systems like Moodle XML or commercial like Blackboard; and application specific like Hot Potatoes or OpenMark, an ad hoc format developed by the Open University of United Kingdom (OUUK).
- **General purpose formats**, whose original purpose is not learning assessment but can nevertheless be applied to it. The chosen formats belonging to this group are DocBook, used to write book and technical articles, FML, for describing Frequently Asked Questions, QAML, specification for question and answers, and SuML, used for writing surveys.

B. Comparative analysis of assessment formats

Once the assessment format metamodels were developed, a series of qualitative comparisons between them were carried out.

First, a set of key features was defined for assessment formats. The selection of features was based on the IMS QTI specification and the conceptual model that will be presented in Section IV:

- **Response and outcomes processing**: the possibility of processing the response given by the student in order to determine if it is correct or not; the processing of several question responses in order to get a global result of the assessment. Response processing can be defined as an external process.

- **Metadata** capabilities: the possibility of storing the metadata of assessment items, sections and tests.
- **Hybrid question** management: the possibility of defining a hybrid question as a combination of a set of simple ones.
- **Correct response** indication: the possibility of indicating the correct response given a concrete question.
- **Multiple responses** related to one question: the possibility of defining more than one response to a given question (one correct and the others incorrect).

Table I summarizes the comparison of the analysed formats regarding the characterising features discussed above. The only common one is the use of metadata, but it is limited to a series of predefined fields like author or date in some formats. Most of them permit multiple responses to one question (only SuML and FML cannot represent it). The remaining features such as establishing the correct response, response processing or using a hybrid question are only supported by the assessment-purposed formats, that is, IMS QTI, Moodle, Hot Potatoes, OpenMark and Blackboard

TABLE I. KEY FEATURES IN ASSESSMENT FORMATS

Formats	*Meta*	*Proc*	*M.R.*	*C.R.*	*Hybrid*
IMS QTI	X	X	X	X	X
Hot Potatoes	X	X	X	X	X
MoodleXML	X	X	X	X	X
OpenMark	X	X	X	X	X
Blackboard	X	X	X	X	X
DocBook	X		X		
FML	X				
QAML	X		X		
SuML	X				

On the other hand, a series of question types have been selected in order to support the comparison between assessment formats. The selected question types have been classified according to the FREMA model [5] into the following sets:

- **Constrained response**: a question whose response is constrained to a space of solutions. That is, the student does not need to write any words, just to select an option from a set. Examples of this type of question are multiple choice questions (MCQ), multiple response questions (MRQ), true/false (TF) and matching.
- **Constructed response**: a question whose response is open, that is, it is constructed by the student. Examples of this type of questions are short-answer questions, essays, fill in the blanks (FIB), crosswords, etc.
- **Miscellaneous/mixed**: questions that do not fit in the previous categories, like practice sessions, simulations, etc.

Taking into account this classification of question types, a set of them has been selected in order to make up a representative sample. The selected questions types, which have been collected from the assessment formats studied in the previous section, are as follows:

- Short answers: a textual answer consisting of a few words.
- Essay: a textual answer with unlimited or limited number of words that is not corrected automatically.
- Multiple choice question (MCQ): choose one option out of a list of possible answers. This type includes True/False (TF) questions.
- Multiple response question (MRQ): choose one, more or no option out of a list of possible answers.
- Fill in the blanks (FIB): complete missing words in a sentence or paragraph.
- Match: given two lists of terms, match each term on one list with one term on the other.
- Crossword: fill out a crossword using definitions of words in horizontal and vertical positions.

TABLE II. QUESTION TYPES IN ASSESSMENT FORMATS

Formats	*Short*	*Essay*	*MCQ*	*MRQ*	*FIB*	*Match*	*Cross*
IMS QTI	X	X	X	X	X	X	X
Hot Potatoes	X	X	X	X	X	X	X
MoodleXML	X	X	X	X	X	X	
OpenMark	X	X	X	X	X	X	
Blackboard	X	X	X	X	X	X	
DocBook	X	X					
FML	X	X					
QAML	X	X					
SuML	X	X					

Table II summarized the comparison of the formats regarding the types of questions supported. Short answer and essays are supported by all formats. Only formats developed for assessment purpose, however, allow multiple choice, multiple response, fill in the blanks or match questions. Crossword is a complex question type that Hot Potatoes supports and that can also be implemented in IMS QTI though in a more challenging way.

III. ASSESSMENT FORMATS USAGE IN EUROPE

As part of the analysis of assessment formats, a study of the usage of standards and specifications for assessments in Europe has been carried out. In order to accomplish this task, two different methodologies could have been followed:

- A quantitative analysis of a larger number of institutions using a statistical study
- An in depth analysis of a representative sample of institutions using both quantitative and qualitative methods.

The second methodology fits the objectives of the ICOPER project and can take advantage of the possibility of analysing, in depth, the institutions inside the consortium. Even more importantly, it is more appropriate for determining, analysing and understanding the underlying causes supporting the evidences found.

Figure 1 shows the distribution of use of the diferenent assessment formats, being the most spread ones IMS QTI, Blackboard and MoodleXML. The IMS QTI specification is considered as a *de facto* standard thus it is not unexpected to see its usage in several cases. Conversely the use of Blackboard can be justified because it is considered as one of the first e-learning tools. With respect to Moodle, (the most used e-learning tool currently) it also appears in the first position of this list. In the studied sample, it can be stated that the IMS QTI specification is used at least as frequently as proprietary formats that belong to two important tools in the e-learning scenario: Blackboard and Moodle. But considering all proprietary and ad-hoc formats as a single set, the ratio of usage of IMS QTI is rather low revealing a lack of acceptance of the specification. This statement is confirmed in [6].

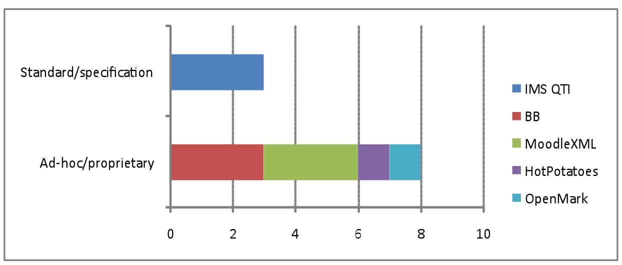

Figure 1. Usage of assessment formats

IV. REFERENCE METAMODEL FOR ASSESSMENT CONTENT

A. Proposal of a reference metamodel for learning assessment content

Due to the deficiencies detected during the metamodels analysis described in Section II and the analysis of required concepts in the assessment environment that will be presented in other paper of this special session, it has been considered necessary to propose a reference metamodel for assessment content.

Three parts have been identified in the assessment formats: presentation, processing and content. This model is focused on assessment content (it is intended to keep it simple to facilitate its adoption). It covers the assessment resources (content) and results (feedback and grade) from the assessment conceptual map. It is designed to provide assessment interoperability, so it avoids ambiguous definitions and duplication of information (such as some of the deficiencies found in QTI, as explained in the paper about interoperability in this special session).

The proposed reference metamodel accomplishes all key features discussed previously except processing, because this service can be externalised. In the same way, the proposed metamodel covers all questions types considered in the qualitative assessment formats comparison. Thus, the reference metamodel can be regarded as a minimum set of entities that accomplish the key features of existing assessment formats. This set is minimum in order to foster simplicity and ease of implementation, which are interesting features from the point of view of interoperability.

The reference metamodel for assessment content comprises all features required for completeness and interoperability in the learning assessment process. The basis of this metamodel is the IMS QTI metamodel and the generalized model created by Zuzana Bizonova in her PhD thesis [7] that is a study of a set of tools that have an assessment module, i.e., Claroline, Moodle and OLAT.

The initial version of the reference metamodel presented some deficiencies, the main one being the lack of support for learning outcomes different of knowledge, i.e., skills and competences. As competence-based learning is one of the ICOPER main objectives, it is necessary that the proposed metamodel cover these types of learning outcomes too. A new version of the model has thus been developed to fix such deficiencies.

The main concept of the reference metamodel, shown in Figure 2, is the assessment item. It represents an assessment entity that makes sense isolated. It is an abstract concept (like an abstract class in a object oriented programming language) that has three types of concrete realizations: question, task and assignment. Assessment items are composed of a definition, that is the wording of the question, and other metadata, like estimated duration of the assessment item or the author of this item.

Questions are used for assessing knowledge (like all the assessment formats studied previously) and they contain some entities related with this task: set of possible responses, correct response declaration and grading/feedback assigned to every possible response (in the case of constrained response questions).

Tasks target the assessment of skills, besides the knowledge that is implicitly used in such skills. They may make use of a series of hardware and/or software tools in order to perform the assessment. For example, ad-hoc software would be required for a simulation of the specific subject being assessed. Thus, tasks cover FREMA question type miscellaneous/mixed that were not covered by questions, although some constructed questions can be also considered as tasks, e.g., essay assesses writing skills.

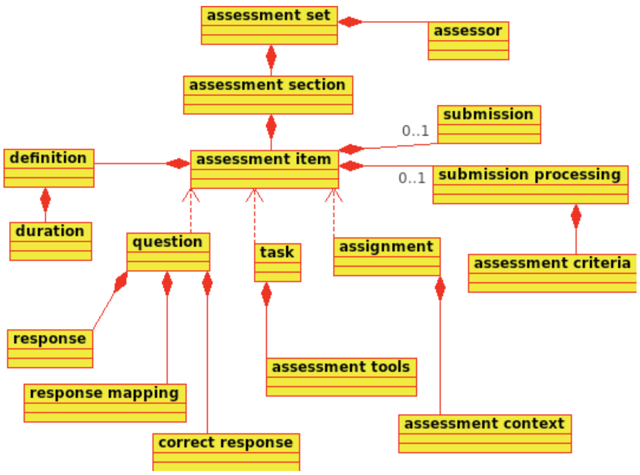

Figure 2. Reference metamodel for assessment content

Finally, assignments are defined to evaluate competences (besides skills and knowledge) and require an assessment context. For example, work in groups can be assessed using a group of students that participate in the assessment process; this group of students is the context when a particular student is assessed.

On the other hand, student response (submission) is associated to assessment item, but this response can be or not be processed. It is also possible that this processing was defined as an external process. This processing is executed following a certain assessment criteria.

Finally, assessment items can be grouped in assessment sections, and sections in assessment sets that would correspond to complete exams. Given a complete example, it could be useful to define the evaluator in charge of this process, that is who assesses the student. The information of the assessor of an assessment set can be used to define the assessment method of this set, what is an important characteristic of this resource. For example, it can be useful as metadata of assessment resources in a repository in order to search automatic assessments (whose assessor is a computer).

B. Validation of a reference metamodel for learning assessment content

In order to validate the proposed reference model, model comparisons between the reference metamodel and the metamodels studied in Section II have been performed. A series of model transformations have been defined ad-hoc for this purpose. Thus, an algorithm has also been defined, which consists of an ordered set of transformation steps. After the executions of these steps, one model should be transformed into the other one; if so, it is demonstrated that they accomplish the same features.

The model transformations that have been defined to compare metamodels are as follows:

- **α-conversion**: an entity or attribute changes its name
- **attribute2entity**: an attribute changes its role to play like an entity
- **extension**: the addition of an entity or an attribute
- **relocation**: the change an entity or attribute position in the model

Once defined the basic transformations, an algorithm is executed consisting on a set of ordered steps. These steps are basic transformations, from a chunk of one model that accomplish a key functionality to a equivalent section in the metamodel that is being compared to.

This methodology has been used to compare the first version of the reference metamodel for assessment content to IMS QTI (version 1.2.1 and 2.1). The comparison results is that the proposed metamodel accomplishes the key features defined before, that QTI was supposed to accomplish based on its analysis. Thus, this reference metamodel was a simplification of QTI model maintaining the defined key features. It is assumed that these conclusions can be extended to the second version of the reference model because it has been built following the same premises of the first one.

V. CONCLUSIONS

In this paper, a study of the most relevant assessment formats and specifications in present day e-learning systems is presented. A qualitative comparison has been performed among the studied assessment formats, following a list of defined key features and questions types. As a result of this analysis, a series of deficiencies have been detected in the studied formats, like the range of supported learning outcomes (limited to knowledge) and the lack of content interoperability. A study of specifications usage has been also presented, concluding that IMS QTI is not used as frequently as expected due to the detected problems [3].

Besides, a study of the concepts of learning assessment has been performed and, as a result of it, a concept map of this domain has been developed. This tool will allow us to know exactly the concepts used in learning assessment and the relationships between them.

Finally a reference metamodel for assessment content has been proposed, which solves the problems found in the specifications study. This metamodel is based on the comparison of assessment formats and the concept map developed previously. It should be also mentioned that the metamodel was defined having in mind assessment content interoperability.

As future work, it is planned the refining of the reference metamodel for assessment content in order to cover all necessary aspects in assessment domain. On the other hand, a data model is also planned to be created, based on the concept map and the reference metamodel, which will allow to carry out an actual implementation of this proposal.

A proof of concept will be executed in the Open ICOPER Content Space (OICS), a federated repository of assessment content, consisting on integrating and managing assessment material. This implementation will be used as validation of the reference model presented in this article.

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Aligning Assessment with Learning Outcomes in Outcome-based Education

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Abstract— **In outcome based learning, learning outcomes (knowledge, skills and competences) to be achieved by learners are in the focal point of the learning process. All educational activities and resources need to be related to the intended learning outcomes of a learning module or course, in order to assist the learners in successfully achieving the intended learning outcomes at the end of the learning experience.**

Outcome based assessment means that the assessment process must be aligned with the learning outcomes. This means that it should support the learners in their progress (formative assessment) and validate the achievement of the intended learning outcomes at the end of the process (summative assessment). It also means that the assessment process should be adapted depending on the kind of outcomes that it is aimed to appraise.

This paper presents an insight into the current state of outcome based learning within Europe and proposes a unified conceptual model for outcome based assessment, shaping a theoretical framework for the integration of learning outcomes, assessment and units of learning as key concepts. An application scenario is finally described to illustrate the application of the model.

Keywords- learning assessment, learning outcomes, unit of learning.

I. Introduction

The European Qualification Framework [1] is proposed to act as a translation mechanism across the different National Qualifications Frameworks (NQFs) in the European countries. Its implementation should help higher educational institutions and workplace organizations across Europe to exchange and compare learning outcomes presented by individuals. The primary goal of the EQF is to improve mobility of learners across European countries and educational systems. Currently, higher education institutions have not yet adopted standards for learning outcome definitions, resulting in inefficiencies for both outcome-based learning design and outcome-based discovery, access and re-use of units of learning [2].

In this paper, the ICOPER[1] project approach for developing outcome-based assessment and units of learning is presented. The alignment of assessment items to learning outcomes to be achieved by learners is discussed in a novel theoretical framework and reference model for assessment in outcome-based educational environments.

II. Key Concepts in Outcome Based Education

A. Learning Outcomes

Learning outcome means statements of what a learner knows, understands and is able to do on completion of a learning process. It covers knowledge, skills and personal, social and/or methodological abilities that a learner should attain when successfully having finished a unit of learning:

- **knowledge** means the *outcome of the assimilation of information* through learning [1]. Knowledge is the body of facts, principles, theories and practices that is related to a field of work or study. Example: *"learners are able to enumerate and explain the eight golden rules of interface design."*
- **skill** means the *ability to apply knowledge* and use know-how to complete tasks and solve problems [1]. Example: *"learners are able to design an interactive website that complies with Web Accessibility Guidelines."* – Note that in order to achieve this skill, learners will need to assimilate knowledge in web programming and web usability. They will be able to do something by applying knowledge, therefore it is a skill.
- **competence** means the proven *ability to use knowledge and skills* in work or study situations and in professional and personal development [1]. One key aspect of a competence is the degree of autonomy and responsibility with which learners are able to apply knowledge and skills. Example: *"learners are able to review the design and usability of a given system and formulate suggestions for improvement based on relevant design metrics and*

[1] http://www.icoper.org

guidelines with minimal supervision by a tutor." – This learning outcome requires the ability to use knowledge and skills: it requires knowledge about user interface design and usability metrics; it requires the skills of being able to do a critical review, apply usability metrics, and suggest improvements to the model. It is a competence because it adds information about the degree of autonomy by stating that learners are able to do this with minimal supervision by a tutor.

IEEE RCD [3] is the only widely accepted standard for describing generic learning outcomes. IEEE RCD is a continuation (and replacement) of the early efforts on the development of IMS Reusable Definition of Competency or Educational Objective [4]. It provides a way to capture the key characteristics of a learning outcome, independently of its use in any particular context or target group (persons). This model should enable the storage, findability and exchange of learning outcomes across learning systems that deal with learning outcomes data.

B. Outcome Based Unit of Learning

Learners aim to achieve learning outcomes by successfully completing a **unit of learning**. Each unit of learning targets the acquisition of one or more assets of knowledge, skill or competence. We define a unit of learning as a contextualized, complete, self-contained unit of education or training that consists of a teaching method and associated content (adapted from [5] p. 25). A three-months distance course on the effects of global warming could be an example of a unit of learning. A one-hour face-to-face lecture on the basics of academic writing could also be an example of a unit of learning. Hence, units of learning may differ significantly for attributes like duration or complexity of activities.

This definition outlines two important properties of a unit of learning: *contextualized* means that the unit of learning is situated in a specific subject context; *complete* and *self-contained* mean that the unit of learning includes all information and resources required including objectives, content, assessment, description of learning and teaching activities, and so forth.

Well-designed units of learning typically follow a strategy or **teaching method**. We define a teaching method as a *learning outcome* oriented set of activities to be performed by learners and learning supporters. Examples of teaching methods are the lecture method, problem-based learning, and the think-pair-share method.

A pivotal piece of information to be included in a unit of learning or teaching method is the set of intended learning outcomes (see Section II.A) that learners are expected to attain upon successful completion of (a run of) the unit of learning. We define that learners have successfully attained a learning outcome if they successfully passed the associated assessment that is part of the unit of learning. Information on the learning outcomes to attain is linked to each unit of learning in the form of learning outcome definitions. As described in Section II.A, we differentiate between knowledge, skill, and competence types of learning outcomes.

Typically, teaching methods are *generic* descriptions of activities, independent of specific content or an application context. Therefore, a teaching method is not directly put into practice by teachers: it needs to be adapted to a specific application **context** that gives meaning to it (e.g. subject, target learner group, IT infrastructure). Teaching methods are thus realized in units of learning within a specific context and with associated content. One unit of learning may employ multiple teaching methods that aim at several learning outcomes.

Another important aspect to be considered for the design of units of learning is the **learning assessment**. The learning assessment specifies which assessment resources and methods are to be used during the learning provision process to assess the achievement of intended learning outcomes. While a generic teaching method typically makes general statements about the **assessment method** (e.g., multiple-choice test, peer assessment, learning contract, oral examination), the unit of learning needs to specify in detail how the assessment method is implemented with a concrete set of **assessment resources** (e.g. tests, test items, peer assessment forms).

There is a design-time view and a runtime view on units of learning. All required descriptive information (metadata) related to a specific teaching and learning process is specified at design time. A running instance of a unit of learning is called a *run*. While each run may involve different groups of learners in different environments, all runs of a unit of learning follow the design specified in the unit of learning. There are many different ways of representing units of learning. Some widely used formats include narrative texts, structured descriptions following a uniform template, or formal machine-readable descriptions using a specialized language (like IMS Learning Design [6]).

C. Outcome Based Learning in Europe

The European Union is confronted with the challenge to make Europe more responsive to the labour market's requirements. In other words, European graduates should be equipped with the appropriate knowledge, skills and competences required by the workplace to meet the challenges of globally increasing competition.

In 1999, education ministers from 29 European countries signed the Bologna Declaration [7] and so committed to establish the European Higher Education Area (EHEA) that should promote coherence in European higher education by 2010. The EHEA is not intended to represent a centralized European-wide system of higher education, but rather offers reference points for national policies and actions, and it guides the implementation of common key features in the respective national educational systems, such as national qualification frameworks. The re-structuring of the educational systems to meet the requirements of the EHEA resulted in a change of paradigm promoting the idea of putting the learner into the centre of the learning process and of concentrating on the intended learning outcomes of this process instead of what has been provided as input by teachers and instructors.

The Bologna process offers the instruments required to bring about the shift from a teacher centred to a more learner-oriented approach to education for formal study programs. That includes the European Credit Transfer System (ECTS) [9] to express students' workload, the two/three cycles system (bachelor, master, PhD), the degree recognition to further the compatibility and portability of study programmes and the European Qualification Framework to make learning outcomes more transparent and comparable across Europe.

Of course, formal learning offerings (e.g. study programmes) cannot satisfy all the requirements of lifelong learners, therefore informal learning opportunities become crucially important. Anyway, integrated support for informal and formal learning is missing. Learning outcome development typically starts in the initial education context, which includes traditional school settings. But dynamic changes in the society and economy increasingly demand lifelong development of knowledge, skills and competences in the work context, encompassing both informal learning activities (i.e. intentional, but not accredited) as well as non-formal ones (i.e. as a side effect of other activities). A holistic picture of the educational process distinguishes its five phases: requirements analysis, design of learning strategy, development of learning offerings, provision of learning opportunities, and evaluation of learning offerings [8]. New approaches are needed to better map learning outcomes to units of learning, teaching methods, assessment methods and records, and context of study and work, analyse learning outcome gaps, and provide informal training to close these gaps. That is in addition to enabling exchange of graduates' learning outcome profiles between universities and workplace systems and between European universities.

In ICOPER, one key challenge will thus be to find ways that can effectively bring together educational achievements attained within formal as well as informal learning settings. That should result in evidence records (i.e. statements about the learner's attained learning outcomes based on assessment) of what a person knows and understands, and is able to do in terms of different application modes of knowledge and understanding at different levels of autonomy and responsibility.

III. Towards a Unified Model for Outcome Based Assessment

The most significant precedent reference model for the assessment domain is FREMA (e-learning framework reference model for assessment) [10]. Since its development, the technology enhanced learning field has however experienced an important evolution, which requires a renovated model. The most significant contribution of the ICOPER model proposed here is its emphasis on learning outcomes orientation, which is in line with current European policies and recommendations framed by the Bologna Process and its efforts towards establishing the European Higher Education Area. An additional contribution is its integration into a global holistic reference model for technology enhanced learning rather than focusing on just one aspect –assessment– of the learning process.

A. Conceptual Framework and Content Space

The ICOPER reference model [11] aims to provide a conceptual framework for common understanding of the learning outcome based Technology Enhanced Learning (TEL) area as well as the interdependencies of its key concepts. The objective is to facilitate the work of stakeholders to design, develop, implement and improve TEL systems with a focus on re-use and outcome based learning. For the field of assessment, a reference model supports the development and implementation process of assessment-related tasks and systems.

The Open ICOPER Content Space (OICS) [12] aims to provide access to integrated educational content and services, and acts as a proof of concept for the reference model. Figure 1 represents the architecture for the OICS.

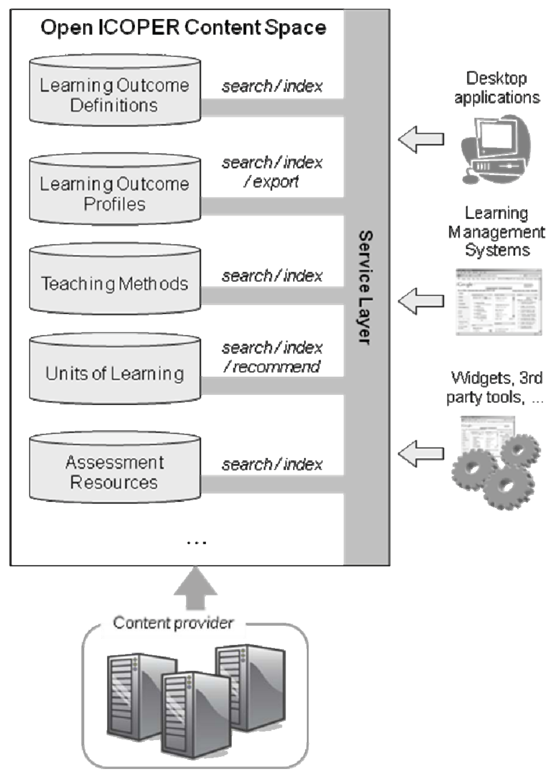

Figure 1. OICS architecture.

The OICS attempts to provide a service-based interface to access educational resources distributed among different content providers thus facilitating re-use. Accessibility of the resources relies on the use of metadata. Original metadata (as stored in the source repositories from content providers) are thus complemented with enriched metadata including complementary information associated to the resources according to the ICOPER reference model. The OICS implements a learning outcomes based approach to learning processes, providing access to the key educational resources defined in the ICOPER reference model: learning outcomes (including both learning outcome definitions as well as

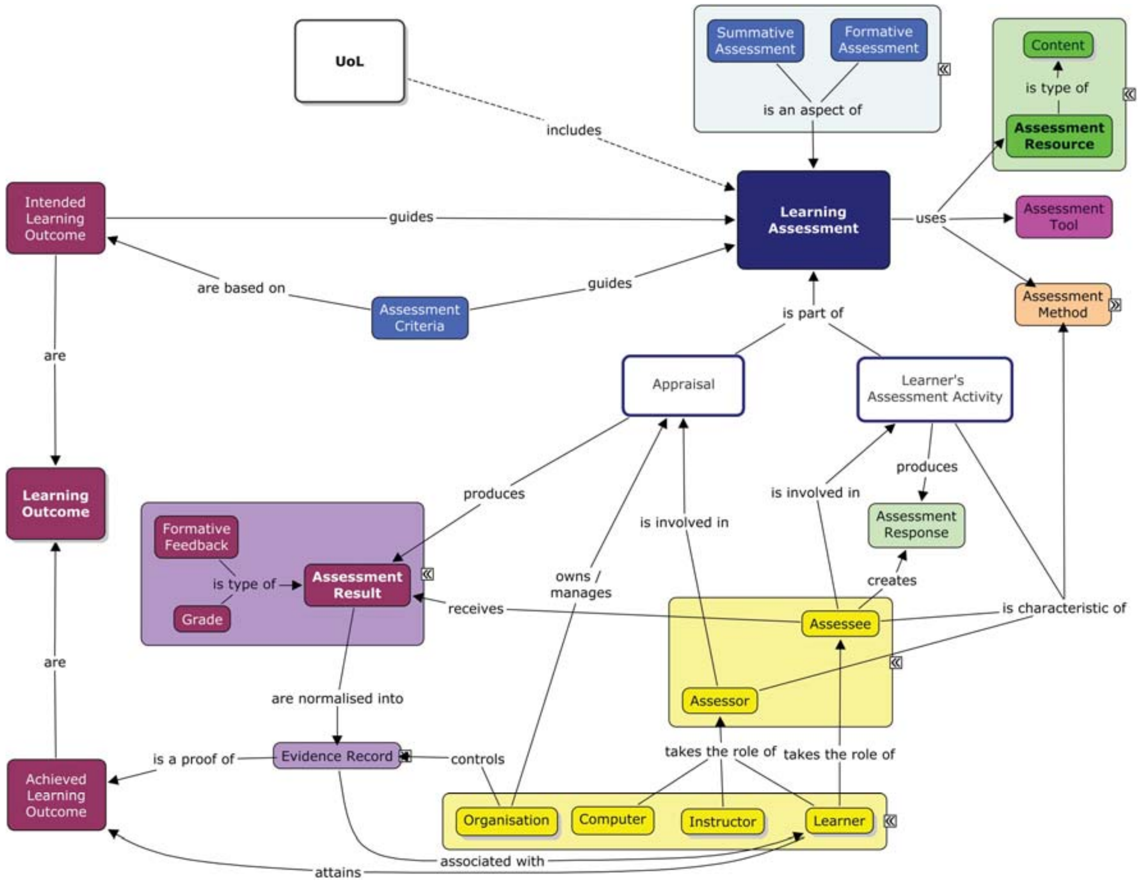

Figure 2 Conceptual map for learning assessment.

learning outcome profiles), units of learning and teaching methods, and assessment resources.

B. Unified Conceptual Map and Reference Model

There are two main concepts in any learning scenario: the learning outcomes that are intended to be achieved by the learner and the unit of learning as the means by which those can be achieved. In order to complete the picture, *learning assessment* appears as the process of testing the achievement of learning outcomes (knowledge, skills and/or competences) by an individual learner and providing the corresponding information reporting about the learner achievements and/or potential indications for improving them. It can be summarised as the process of identifying, collecting and preparing data to evaluate the achievement of the outcomes and educational objectives of a program [13]. Learning assessment is thus the binding process by which the intended learning outcomes defined by a unit of learning are accredited as actual learning outcomes acquired by a learner, transforming those learning outcomes from potential to factual.

The unit of learning makes use of the learning assessment process, in order to verify that the learner who participated in the unit of learning attains the intended learning outcomes. Learning assessment processes can be integrated into a unit of learning as activities which imply a response by the learner, and also generate information about his/her performance as results.

Two representative cases can thus be considered [14]. On the one hand, a unit of learning which includes a final assessment process to check whether the learners have successfully accomplished the intended outcomes. That is, a summative assessment, which provides a measure of achievement or failure, made in respect of a learner's performance in relation to the intended learning outcomes of the program of study [15]. An example of such a case is an exam at the end of a course on Object Oriented Programming. The unit of learning is in this case the course itself, which includes a series of lectures, programming exercises in the laboratory, etc. In order to adequately cover the assessment of the expected learning outcomes, the exam would be composed of a theoretical part with multiple choice questions addressing knowledge outcomes of the course *(e.g. Explaining the concepts of Object and Class)*; and a programming assignment for evaluating the student’s programming skills *(e.g. Developing a software program which involves inheritance)*. The learning assessment concept (cp. Figure 2) would comprise the whole process, including in this case both the activity of the learners taking the exam as well as the appraisal phase when the instructor gauges the learners’ responses and awards them the corresponding grades.

On the other hand, a learning assessment process can be a learning activity itself, aiming to provide formative feedback to the learner about his/her performance and support their progress [16] [17]. An example of this case is a peer review activity integrated as part of the unit of learning. Following the previous example, the same course on Object Oriented Programming includes a peer review activity consisting of assessing a programming project developed by the learners organized in teams of four members. Such activity aims at generic learning outcomes such as team-working and critical evaluation, in addition to other domain specific outcomes. The learning assessment can again be subdivided into two sub-processes: the development of the project by the learner (learner's activity) and the reviewing (appraisal).

Further analysis of the relationship between learning outcomes, unit of learning and learning assessment requires the introduction of the key concepts related to the latter: assessment resource, roles (assessor and assessee), assessment results, etc. Figure 2 represents these key concepts as well as the relationships interconnecting them.

In a similar way that a unit of learning uses learning resources for supporting the learning process, an assessment process also makes use of specific content. An assessment resource is a special type of learning content, which is used for assessment purposes and it involves interaction with the learner. Examples of assessment resources would be the test in the first case, with the set of questions and the programming assignment instructions. And for the second case, the assessment resource is the project proposal together with the rubrics and questionnaires for the peer reviewing. Assessment resources should include additional information besides the textual instructions provided to the learners. For example, information about the correct answers for the multiple choice questions in the first case.

Such assessment resources are proposed to be represented using the IMS Question, Test & Interoperability (IMS QTI) specification [18] (considered nowadays a standard de facto for assessment resources) enriched with extended metadata. Such metadata includes information about the learning outcomes (knowledge, skills or competences) that are tested by the assessment resource.

Two roles are involved in the assessment process: the assessor (responsible of the appraisal) and the assessee (whose learning outcomes are appraised). They typically correspond to the learning supporter and the learner roles defined for the unit of learning, respectively.

As a product of the appraisal done by the assessor, the assessment results are generated, consisting of information about the performance of the assessee, his/her achievement of the learning outcomes and/or formative feedback for supporting the learner's progress. Usually, assessment results can correspond to specific learning outcomes and may need further post-processing to inform about more generic learning outcomes. For example, it may be necessary to combine results from several assessments to accredit the attainment of a certain learning outcome. On the contrary, it is also frequent that a given assessment process considers several different learning outcomes. Here there is a need for a normalization process that transforms detailed assessment results into *evidence records*, which act as proof of the attainment of learning outcomes and can be included in the learner's *learning outcome profile*.

The evidence record acts henceforth as the binding between the learning outcomes that the learner can actually claim and the assessment process (when successfully completed). In order to be trusted and to provide complete information, evidence records should include data about the type of assessment performed as well as the responsible expert and institution that endorses this evaluation.

Finally, the description of the assessment process is formalized into the *assessment method* concept, which comprises the characteristics defining a certain assessment process (such as who plays the role of assessor, the type of activity posed to the assessee, the purpose of the process, the kind of results to be provided, etc.).

The assessment method is strongly influenced by the assessed learning outcomes. Different types of learning outcomes require different assessment methods. For example, knowledge-type learning outcomes can be assessed using multiple-choice tests while such kind of activity is less appropriate for assessing skills. Assessing the fluency and pronunciation skills of a learner in a course on English as a foreign language would imply the use of oral activity; whereas a written assignment may be used for assessing a learner's writing skills.

Different assessment methods can also be defined depending on the actors playing such roles. The assessor role can be played by the student him/herself, peer learners, the instructor or automatic assessment. Regarding the assessee role, learners can be assessed individually or in groups (collaboratively). Again, the learning outcomes can be determinant in the selection. Critical thinking is usually dealt with by self-assessment, and peer assessment is typically applied when evaluation skills are intended outcomes.

The assessment method is thus a concept that can be related to the teaching method defined for the unit of learning, as it plays an equivalent role for the learning assessment (namely, the generic description of the process) and can thus be considered an integral component of the teaching method. So the teaching method includes references to the assessment method(s) to be applied when learning assessment activities are included.

In the examples discussed above, different assessment methods are applied. In the final exam case, the assessment method consists of an individual, time-limited (duration: 2 hours), face-to-face written exam, combining a (constrained) multiple-choice test with a (constructed) development assignment; responsibility for appraising the learner responses corresponds to the instructor, who plays the assessor role; the purpose of the assessment is summative and grades are the only assessment results generated (no formative feedback is intended). Conversely, the assessment method in the second case (formative peer review activity) consists of a team project assignment (teams composed of four members), peer learners play the role of assessors and the purpose of the assessment is formative, thus formative feedback is provided to the learners as assessment results.

Figure 3 shows the conceptual map for the proposed learning outcome based assessment model, abstracting the detailed concepts and focusing on interconnecting key ones.

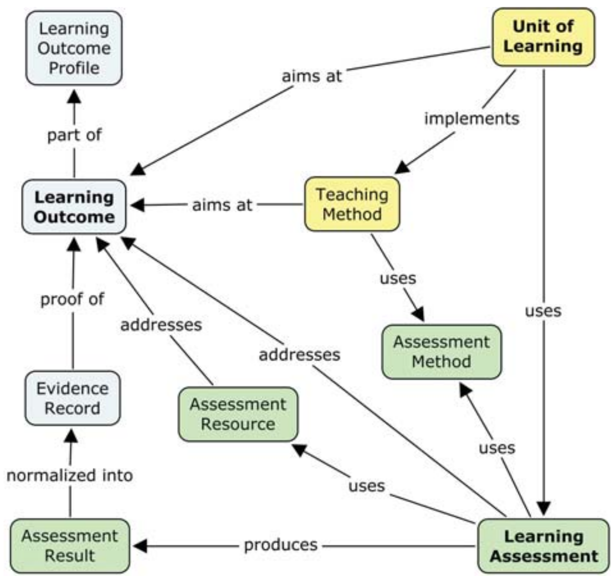

Figure 3 Concept map for learning outcomes-based assessment.

In summary, learning outcomes and assessment are connected in two ways:

- At design time: learning assessments are designed to evaluate the attainment of certain *intended* learning outcomes.
- At runtime (or provision time): learning assessments provide information about *actual* learning outcomes achieved by a learner; the assessment results are normalized into evidence records.

Typically, learning outcomes are acquired through participation in a unit of learning, and learning assessment can thus be integrated in such units of learning. Occasionally, learning assessment processes can stand independently, when aimed at just certifying the achievement of learning outcomes without an associated learning process.

C. Case Study

In this section a case study is discussed to illustrate the implementation of the unified model presented earlier. It aims at being a proof of concept for the model and to clarify the definition and connections of the key concepts. In summary, it consists of a basic English unit of learning composed of lectures, exercises, and a final assessment intended to evaluate the actual learning outcomes acquired by the learners.

During the design phase, the first step is to define the intended goals of the educational process, i.e., the intended learning outcomes. For this specific unit of learning, the learning outcome belonging to the skill category was specified as: *"Applying English grammar rules in everyday situations"* .

Following the definition of the learning outcomes addressed by the unit of learning, the next step is to define the process that will be used to assess the achievement of the learning outcomes. In this case, the assessment method will be one final exam, consisting of a multiple choice test, which is intended to be graded automatically by an assessment tool embedded within a Learning Management System (LMS).

Next, the teaching method to be applied needs to be defined. This sample course is taught using a series of lectures coupled with exercises that learners either perform individually or in pairs. A reference to the assessment method to be deployed (described above) is also required to be included in the teaching method description.

Once the structure of the course has been defined, the design process is completed with the selection of the learning resources (content) to be used, either creating new ones or re-using existing content. For the assessment process, such content would be the final exam used to evaluate the learners at the end of the course. In this example, this assessment resource is a multiple choice test on basic English grammar and vocabulary, consisting of a set of questions with the possible alternatives, including information about their correctness (to allow automatic grading).

Figure 4 shows the materialisation of the concepts defined in the proposed unified model for the case study discussed.

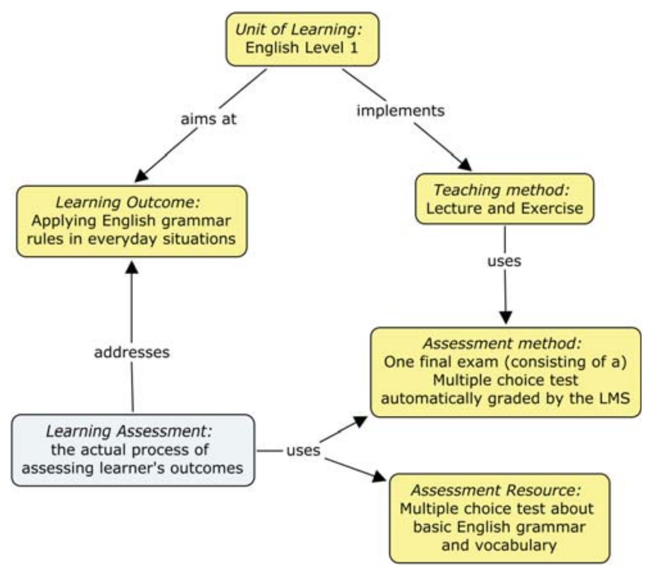

Figure 4 Outcome based assessment case study

IV. Application Scenario

The following application scenario illustrates the benefits of the proposed model for various stakeholders in the educational process both at design-time and runtime.

A. Context

A teacher is preparing a unit of learning about programming in the assembler language for the Pentium CPU. Intended learning outcomes at the end of the unit of learning comprise the following:

- *Knowledge*: being able to identify and name elements of the Intel Pentium CPU architecture
- *Knowledge*: being able to state the instructions of the assembler language
- *Skill*: being able to code a simple program in assembler including loops, conditional structures, and routines

B. Design time: preparing the learning activities

The teacher wants to provide the students with a formative assessment to be taken during the learning process, consisting of a test so that they can check their understanding of the basic concepts. The teacher, using a search functionality in an LMS that is connected to the Open ICOPER Content Space (OICS), searches and retrieves a test adequate for the domain, level and learning outcomes requirements.

The teacher also needs to include a final learning assessment which assesses if the students have successfully achieved the intended learning outcomes declared in the unit of learning. Thus, she searches the OICS for assessment resources adequate for the unit of learning (skill: being able to code a simple program in assembler). She finds a resource consisting on an assembler programming project (which should be developed by the students) accompanied by a rubric that will enable her to evaluate the validity and completeness of the coded program.

C. Runtime: updating the learners' leaning outcomes profiles

Once the unit of learning is completed, the learners' learning outcome profiles are automatically updated, for the learners who have successfully passed the learning assessment used in the unit of learning, to reflect the newly achieved learning outcomes with additional associated data like evidence records (e.g. certificate) and context (e.g. subject domain) of the unit of learning.

D. Conclusions

The scenario discussed above illustrates some of the advantages of the proposed unified model, which benefits a variety of stakeholders.

Authors and *teachers* can search for assessment resources adequate for appraising the achievement of the intended learning outcomes; either for supporting the learning process (by detecting gaps between the intended learning outcomes and the actual ones achieved by the learner), or for certifying the final achievement of the learning outcomes at the end of the process. This facilitates the design process.

Learners also benefit as they are provided with quality material which supports their learning process for achieving the desired learning outcomes, as re-use is expected to help refining and improving such resources. Additionally, learners would also have a learning outcome profile which reflects their state of achievements and is kept up-to-date automatically and transparently.

Finally, *other stakeholders* such as companies or employers may also benefit from applications of this unified model. The learner's learning outcome profile would provide a potential employer the information required for assessing the applicant's suitability for a given position. Additionally, knowledge management programs aim to provide (among other objectives) specific training to the employees according to their actual knowledge, skills and competences and the requirements posed by their job positions. Learning outcomes-based assessment would allow searching for specific assessment resources in accordance with knowledge gaps and define tailored training programs. Learner's assessment is perhaps one of the areas where this combination is proving to turn into a richer symbiosis. Information and Communication Technology (ICT) strongly facilitates the management of the assessment process, leveraging the teaching burden associated to it [19]. But apart from the logistic support, ICT empowers potential benefits of the assessment process (for example, fostering immediacy of feedback) as well as open new scenarios for student evaluation.

V. Conclusions and Future Work

Educational processes are shifting towards a learning outcomes based approach in the active learning model. Knowledge, skills and competences achieved by the learner play an increasingly important role as the professional life introduces new lifelong formative challenges. Learning assessment cannot be oblivious to this paradigm shift, either aiming at formative purposes in active learning or as a mechanism for accrediting the attainment of knowledge, skills and competences.

In this paper, a novel theoretical framework has thus been proposed for learning outcomes based assessment. The proposed ICOPER model captures the influence of learning outcomes in the learning assessment process, which determines appropriate assessment methods and resources to be used. Assessment plays a key role in acknowledging that a learner has attained the intended knowledge, skills and competences. This model is contextualised in the broader framework of outcome based learning, based on the unit of learning as the means by which the learners achieve such intended outcomes. Illustrative examples of scenarios and case studies are also provided to clarify the practical use of the model.

Future work includes the definition of a detailed taxonomy of assessment methods and an analysis of the appropriateness of the different assessment methods depending on the learning outcomes to be assessed. Also, ongoing work is aiming at developing a complete metadata model and binding that enables implementation and interoperability of the concepts in the unified ICOPER model in educational resource repositories (such as the Open ICOPER Content Space). Such analysis will provide a best practices guideline for learning outcomes based assessment that facilitates the actual deployment of this approach.

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Current Issues With Assessment Formats and Interoperability

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Abstract—**Assessment has been one of the areas in computer supported learning where technology has been quickly deployed. Support for computer based assessment is found not only in all Learning Management Systems, but also as stand-alone tools. This large number of tools has led to the appearance of a large number of formats to store, retrieve and exchange assessment material. Although institutions such as the IMS Global Consortium have proposed specifications (e.g. IMS QTI) aimed to facilitate the exchange of this material, in the actual landscape, there are still too many formats that significantly hinder the reuse of this material. In this paper an analysis of the implementation of these formats is described.**

Keywords-assessment format, interoperability, IMS QTI

I. Introduction

In today's e-learning, the advance and support offered by technology is very uneven. Some aspects of a learning experience are fully supported by technology (for example assessment), whereas in others, technology is barely beginning to appear (for example, integration of generic services in a learning environment). Assessment has been one of the aspects where technology has had a very strong presence from the early times. Some computer-based assessment tools even pre-date the appearance of some learning management systems (henceforth simply LMS).

The issue of storing assessment material is intrinsic to computer supported assessment. Once a scenario where any form of computer supported assessment is performed the problem of how the material is stored and retrieved already appears. There are two dimensions in which this problem can be solved. The first one is considering only a single tool or product. In other words, given a tool for computer-based assessment (or an equivalent functionality present in a LMS), how can the assessment material be stored and retrieved by any instance of this tool.

But this issue, combined with the wide variety of solutions for computer-based assessment that are currently available, poses a second problem, that of interoperability. Suppose a scenario where Institution A has a rich set of assessment material that created using Tool A (or its equivalent service in the corresponding LMS). Analogously, Institution B has also a rich set of assessment material, but it was created with Tool B. Both tools are totally unrelated and therefore, store the assessment material in completely different formats. So far, none of the tools has acknowledge the other format as one that is supported. These two institutions have identified the potential of sharing this material, but it is not possible with the current formats.

The problem, then is to go beyond formats locally used by specific tools to a format that allows the exchange of assessment material among unrelated tools. The approach followed by international bodies such as the IMS Global Learning Consortium [1] has been to gather a set of experts in the field, analyze the current scenarios where computer-based assessment was being used and propose a format such that any tool would be using to both export and import assessment material. This format proposed by the consortium is IMS Question and test interoperability [2], henceforth IMS-QTI.

The appearance of this specification changed the landscape of assessment formats. For any tool providing computer-based support, the question of supporting IMS-QTI appeared. But the evolution of this specification over the last nine years shows numerous examples of the effect of several design decisions. Of course, it easy now to evaluate how appropriate a specification is to represent assessments. But computer based assessment has reached a stage which can be considered main stream and therefore there is some value in looking back and see how the once foreseen effects really shaped. In the following sections an analysis of the current landscape with respect to this format is analyzed. First a brief description of the aspects covered by IMS-QTI and the different available versions is given. Then a brief account of the type of support offered by the different tools is described. It follows the description of a case study in a scenario in which true cross-platform interoperability was needed. Finally, some conclusions are proposed to improve the level of interoperability among current computer-supported assessment tools.

II. IMS Question and Test Interoperability

The IMS Question and Test Interoperability format was initially proposed by the IMS Global Learning Consortium and its version 1.0 was released as a public draft in February of 2000 and as a final specification in May of the same year. The proposal was based in QML, a structured language proposed by Question Mark Computing Ltd [3] in 1997. The idea behind this format is to capture the structure of assessment material with as least information as possible about how it should be visualized. The format used a syntax similar to an XML document, and even an XML Schema definition has been published.

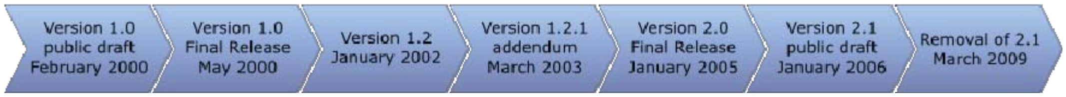

Figure 1: Evolution of the Question and Test Interoperability Specification

In general, IMS-QTI describes the structure for representing two elements: the question, and the assessment. The structure of a question includes information about the body of a question, possible answers, feedback and even grading procedures. The structure of assessment is more related to how a set of questions are organized, subdivided into sections, and how are the values obtained from individually grading the questions are combined to obtain an assessment grade. With this structure, the objective of this format was to allow the exchange of three elements of computer-based assessments: items (that is questions), assessments (different groups of items) and results.

After the first version, the consortium published version 1.2 two years later in 2002 which included a much more comprehensive set of documents describing its structure. Aside from a description of the information model, XML bindings and a best practice guide, version 1.2 also included documents describing how to select and order items, how to process outcomes, how to report results and an overview document. The evolution of the specification is shown in Figure 1.

But the aim to cover the three aspects of assessment management (questions, assessments and result manipulation), led to a specification that was fairly elaborated. As a consequence, a simplified variation of QTI version 1.2 was released with the name of QTILite. QTILite is a subset of QTI version 1.2 that represents an entry level into version 1.2. The main simplifications were:

- Reduced number of question types: Yes/No, True/False, Likert scales and multiple choice.
- Simple response processing with default mechanisms.
- No support for hints, solutions, etc.

As a consequence, tools supporting QTI had to choose between two versions (one a subset of the other) to guarantee some degree of interoperability. Some small amendments were introduced in Version 1.2 to obtain version 1.2.1 in March of 2003.

The next significant leap in the specification came with version 2.0. The assessment process needed to be taken into account but as yet another piece of the complex mosaic of e-learning procedures. For example, an assessment could be included in a more complex set of activities that need to be sequenced following certain rules. The result of an assessment could be used to decide the sequencing of activities (as it is conventionally done in multiple learning scenarios). Version 2.0 was conceived to accommodate this new emerging reality as well as to polish certain aspects from version 1.2.1. This major version change came when several commercial e-learning systems had already included support for QTI v 1.2.1 and meant an additional effort to accommodate the proposed changes.

But to guarantee that this reviewing process reached the e-learning community quickly, the scope of the changes was intentionally reduced to individual assessment items. The aspects of aggregation of items into sections and assessments and result reporting were left out of the review.

These two aspects were reviewed and published as a first public draft (revision 2) a year later in June 2006. Both aggregation and result reporting support were reviewed. At this point, tools supporting version 2.0 of the specification were scarce, and the lack of activity in this draft to become a final specification led the consortium to remove it. The reason was the lack of activity to push this specification forward. As a consequence of this decision, numerous institutions complained that they needed the specification to guide their current developments. As a conclusion, it seems that there is a number of companies and institutions using version 2.1 of QTI, but the participation of these institutions in the process to push the specification to a final stage is scarce. Although the specification was later re-published, the consortium warns that as is, the document is incomplete and in the process of evolving it based on input from the market participants.

Angel		2.1
ATutor	1.2	1.2, 2.1 (experimental)
Clix	1.2	1.2
DB Primary		2.0
Diploma	1.2, Lite	1.2, 2.1, Lite
Dokeos	1.2	1.2, 2.0
.LRN	1.2	1.2
Moodle	1.2	2.0
OLAT	1.2	1.2
QTI Tools	2.1	2.1
QuestionMark Perception	1.2	1.2
Respondus		1.2
Sakai	1.2	1.2

Table 1: QTI support in different tools

The future of the QTI specification is a bit uncertain. Although version 1.2.1 seems to be widely used (the IMS Common Cartridge initiative [5]includes it as part of its formats), and the need for an improved version is perceived, there is not a clear path on how to obtain such improved version.

III. TOOLS SUPPORTING QTI

With this landscape, tools for computer-based assessment started to choose which version of the QTI specification support. A summary of this support in only a subset of e-learning tools is shown in Table 1.As it can be seen, version 1.2 achieved a fairly high level of support. This support has been increased as a consequence of this version being in included as part of other initiatives within the consortium such as IMS Common Cartridge [5]. This format bundled together two previously created specifications, IMS Content Packaging version 1.2 and IMS QTI version 1.2.1 together with additional meta-data to manage learning content from the point of view of the producers as well as the users.

The final consequence of this situation is that when it comes to capture the structure of assessment material such that it can be exchanged among different tools, the most widely supported format is version 1.2.1 which has not evolved since 2003.

IV. ASSESSMENT INTEROPERABILITY: A CASE STUDY

In order to experience first hand the problems that arise when trying to exchange assessment information among unrelated LMSs, an case study was prepared. The study has been carried out within the frame of the ICOPER project. This project is a Best Practice Network that started in September 2008, funded by eContentPlus programme of the European Commission. As part of the ICOPER objectives, an analysis of the best practices in the scope of assessment, and more precisely in the issue of interoperability has been proposed. The project must explore also the different level of adoption of the specifications and standard currently used in e-learning, and the issue of interoperability has been identified as one of the main burdens to overcome to increase adoption.

The case study was designed to include several institutions related to higher education (both educational institutions and commercial vendors) and explore the problems that appear when trying to exchange assessment material. The organizations involved in the study were the Open University of the Netherlands, Giunti Labs, IMC Ag and Carlos III University of Madrid.

The objectives of the study were:

- Obtain a sample of the tools and formats being used to perform computer-based assessments
- Identify the interoperability problems

The type of interoperability problems that were specifically targeted were:

- Exchange of assessment material at the level of "exams", therefore, not only at the level of question items.
- Exchange of generic exam annotations.
- Connection with Learning Outcomes.

The LMSs used by the institutions participating in the study is shown in Table 2.

	Moodle	.LRN	Clix
UC3M	X	X	
Giunti Labs	X		
OUNL	X		
IMC			X

Table 2: LMSs used by the different institutions in the study

The first step was to analyze the import/export capabilities of the LMSs to see which information exchange flows were possible. The format that was commonly supported by the three sampled LMSs was (as expected) IMS QTI. The support for QTI import/export in its different versions is shown in Table 3.

The first observation from the table is the total absence of any kind of support for QTI version 2.1. These three LMSs were implemented when version 1.2 was available, and the migration to the new format was not considered. A different situation appears when considering QTI 2.0. A partially implemented export module was found but with significant shortcomings. The module simply placed a subset of the information contained in the questions in certain special fields of the QTI file but certain special information was not included. The file exported by Moodle then, was not possible to be used in any other platform (nor even Moodle itself because it lacked the import functionality).

	QTI 1.2	QTI 2.0	QTI 2.1
Moodle	No	Export	No
Clix	Import/Export	Import/Export in development	No
.LRN	Import/Export	No	No

Table 3: Import/export support of different QTI versions

Several attempts at providing support for QTI in Moodle were detected in the developers community, but none of them was considered mature enough to be considered. A special situation was seen with respect to the Respondus [7] tool. Respondus is a tool for designing and deploying assessment in e-learning platforms. In principle the product is self-contained, that is, it offers an authoring environment to produce assessment and a deployment environment to use them in a learning experience.

But in order to increase the interoperability, the company produced what is called a "Respondus plug-in" for Moodle that imports assessment material create with these products into a Moodle platform using QTI version 1.2. Being a separated assessment product, the company already has modules to incorporate assessment material created with their product suite into the main LMSs (Atutor, Blackboard, eCollege, etc.) but in the case of Moodle, and because the product is open-source, the uploading of material is based in QTI version 1.2.

This plug-in could be considered as a suitable vehicle to import generic QTI documents into Moodle, but a closer inspection quickly revealed that the QTI produced by

Respondus to be then imported into Moodle was not compatible with the other LMS in the study. The company itself clarifies that the module is not a regular QTI importer but one specifically for the Respondus system. The main reason to avoid claiming to have a generic QTI version 1.2 importer is because only certain uses of the specification are supported. A generic QTI file using other aspects of the specification cannot be handled by this importer.

As with the rest of LMSs, in principle, a potentially effortless exchange of material was possible between .LRN and Clix (if QTI version 1.2 was used). However, upon a closer inspection, again the difference in implementation in the import/export functionality of different platforms made this possibility non-trivial.

The main difficulty when exchanging assessment material is the level of flexibility offered by the specification. There are several forms in which a set of questions making an assessment can be included in a file and comply with the QTI specification. The existence of these different versions, although potentially positive from the point of view of flexibility it is a huge obstacle for interoperability. The amount of possible scenarios to consider when writing an import module derived from the specification rules it too complex.

Furthermore, the specification, to increase flexibility, leaves a large number of elements totally optional. This functionality also poses problems. For example, institution A exports a large number of true/false questions, but none of the questions in the file mark the correct answer. The file would still be in compliance with QTI, yet, most of the current tools would rule it unusable, or even worse, produce an incorrect import.

The trade-off between flexibility and widespread use needs to be carefully considered. Widespread use is very important for a specification such as QTI to be truly useful. But if the adoption is in part fostered by a specification with too much flexibility in its definition, the adoption will be uneven and interoperability will be significantly reduced.

A promising venue that is being explored to compensate this situation is the use of "profiles". A profile is a simplified or reduced version of the specification derived from a concrete scenario of application. Several initiatives have appeared that have contributed different QTI profiles such as, for example, questions in the area of mathematics.

The interoperability problem can then be re-stated in terms of profiles. Two platforms may exchange assessment related information effortless as long as they are encoded using the same QTI profile. But again, the essence of a common specification is lost.

Together with the problems when exchanging information about assessment, the study case revealed some interesting new venues to explore. None of the institutions participating in the study was annotating assessments or question items with information obtained from their use.

Although QTI, with its great flexibility, allows the inclusion of almost arbitrary meta-data, this type of annotations, although perceived by all participants as relevant, were not present in any of the used samples. The process to back-annotate assessments is still far from main stream and requires still an intuitive tool to facilitate the work. This type of annotation becomes very important when assessment material is shared in a wider scope such as federated searches of learning material.

There are currently multiple initiatives to offer federated content available to multiple institutions. The key feature to offer is a powerful search functionality. But a powerful search itself is based in a powerful labeling of the pool of available objects.

|In the context of assessment, if a teacher is searching for relevant assessment material, the search engine should know what type of questions are included in an assessment, if they have been used successfully, the type of scenario in which they were used, etc.

An the third shortcoming found in the study is the lack of connection between QTI and the higher level instances in which it develops. An assessment is usually tied to some sort of learning unit. Even worse, the objectives of a learning unit (in the most general sense) should be connected with the assessment methods, and more precisely with assessments described in QTI.

But this connection between assessment and learning outcomes (learning results, learning objectives, etc) is totally absent from today's elearning landscape. In the future, when massive amounts of learning resources are made available, the search engines should find the appropriate resources to achieve a given objective and attach the appropriate assessments to them. In order for this relation to be detected, it needs to be explicitly included in the document capturing the assessment.

V. RECOMMENDATIONS TO ENHANCE INTEROPERABILITY

The case study described previously showed several venues that can be explored to increase or enhance the level of interoperability of QTI and assessment material in general. Although we are certain that perhaps all of them were discussed by the groups of experts that designed QTI, we think there is some value in reviewing them, specially after the significant changes that re-shaped the e-learning landscape in the last years.

A. Simplification of the specification

The specification tries to cover with its structure a large number of scenarios with almost no adjustments on the scenario side. Although desirable, this is unrealistic. A simple specification capable of capturing all scenarios, even when some adjustments are needed should serve the purpose of interoperability better. Profiles are an example of this pragmatic approach. If the specification comes closer to these profiles (yet remaining unique), the need for a special solution for a specific context might decrease.

B. Focus on the essential aspects

The aim of the initial specification was to cover perhaps too many aspects of the assessment scenario. One example of the vast set of possible situations is grading. The number of possible grading policies is enormous. Providing a specification to describe all of them is equivalent to design a new programming language, or some new calculus notation. In our experiences, the basic functionality expected from the teaching staff when it comes to exchange assessment material is to be able to obtain a set of questions and answers from a given topic from a colleague. The instructions about how this material is graded is typically considered as highly dependent on the context of the assessment and therefore not perceived as essential.

Something analogous happens with the structure used to group a set of questions. In a certain course in an institution, a set of questions should be organized with a fairly special structure. If the course is divided into three topics and they need to be passed separately, the exam should reflect this situation. But when these questions are re-used in a different institution, these details are very unlikely to be re-used. Thus, a format leaving out this information would have a higher probability of being used.

A similar situation appears when assessments are transformed in “sequences”. That is, rather than having a set of questions that are shown to the students all at once, there is some agent in charge of showing some of these questions, and even deciding which ones to show. This type of functionality, as in the case of the exam structure is highly dependent on the context. A better approach could be to adopt a “separation of concerns” approach. The set of questions are perfectly captured by a specification, and the different sequences to consider are the role of another specification that can be used in combination with the previous one. With this approach, institutions only interested in the plain exchange of questions would still be tempted to adopt the appropriate format.

C. Follow an incremental approach to deployment

This aspect is related to the previous one. For the sake of completeness, it might be necessary to tackle some additional aspects surrounding assessments. In the previous section we argued that a clearly separated set of formalisms could be more appropriate. Together with this approach, a gradual deployment of these different specifications could greatly increase the level of adoption.

More precisely, if institutions have a simple path to question interoperability and make that an essential part of their day to day operations, they could be less reluctant to adopt a specification than enhances their procedure.

For example, if institutions exchange questions and answers with a simple specification, they would be more likely to adopt a specification to relate those questions with precise learning objectives that are already included in their courses. Providing a global and exhaustive solution in one single specification can be perceived as a much steep adoption curve and requires a more intense effort.

D. Acknowledge context without increasing the complexity

Considering assessment as a stand-alone e/learning process is no longer acceptable. In the past, many courses would perform assessment procedures in platforms or contexts completely disconnected with the rest of a learning experience. But a proper design methodology needs a strong binding between learning objectives, activities, and assessment. Any specification to formalize assessment must be aware of this connections, although at the same time should minimize its impact in the complexity. Connecting an assessment with a set of objectives not only makes sense when designing a learning experience, but also allows that assessment to be easily found when searching for material in a much larger repository.

But the inclusion of these connections cannot mean a significant increase in complexity. Perhaps the most appropriate approach is to decouple these connections into its own formalism that may flourish on its own depending on the adoption, but at the same time maintains question management at a reasonable level of complexity.

VI. Conclusions

A review of the most important issues in the context of assessment formats has been presented. Although the IMS QTI specification was conceived to offer a formalism to facilitate the exchange and reuse of assessment material among different platforms, the landscape after several years of evolution is somewhat confusing. QTI Version 1.2.1 has a significant level of support, although its intrinsic degree of flexibility turns into difficulties when it comes to implement a fully compliant import/export agent in a tool.

The scope of the specification as well as the number of structures and annotations that are considered optional offers a wide spectrum of possible solutions to encode assessment material. This richness has turned against interoperability as the complexity derived from this large number of solutions needs to be absorbed by the import/export agents.

A case study has been presented in which four institutions related to education (two universities and two e-learning commpanies) tried to exchange assessment material based on the IMS QTI specification. Three learning management systems were studied from the point of view of compliance with the process.

The study clearly shows the complex landscape derived from the flexibility of the QTI specification. Only two of the three platforms considered had the functionality to import/export assessment material in a common version of QTI. And still, the process could not be accomplished automatically because the resulting QTI files needed to be manipulated to accommodate certain specific features of the import/export modules of the other LMSs.

The recommendations to increase the adoption of QTI derived from this study are presented along four main strands|: simplify the specification, focus on the essential aspects of the assessment procedures, follow an incremental approach for deployment and acknowledge the context in which assessment is taking place without increasing the complexity.

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Collaborative Subjects for Embedded Systems Learning in the EHEA Frame: A Practical Approach

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Collaborative Subjects for Embedded Systems Learning in the EHEA Frame: A Practical Approach

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***Abstract*—This paper presents a teaching experience related to the learning methodology in embedded systems within the European Higher Education Area (EHEA) frame. A Problem Based Learning (PBL) methodology has been applied for combining two courses of a bachelor degree in computer systems. The objectives are the integration and application of previously acquired and new knowledge to create an application for the supervision and control of a mobile robot. Technologies used during the development of the project include real-time programming using Ada language, digital control theory and communications.**

***Index Terms*—PBL, real-time systems, digital control, supervision.**

I. Introduction

TRADITIONALLY, technical courses at engineering degrees are organized following a logical sequence, being the earlier the base for the later. However, almost no effort is put on presenting the students with the idea that the integration of the different knowledge and technologies acquired along the different courses, is a fundamental skill in order to be able to solve complex multidisciplinary problems, like the ones they will have to face at disciplines like systems engineering, computer systems engineering, or embedded systems engineering [1]. After completing an engineering degree, the students end up with a wide collection of weakly related concepts and skills organized as watertight compartments [2]. This paper describes a model to mitigate this main drawback by combining two courses in a collaborative way. These courses are Supervision and Control of Systems (SCS) and Real-time Systems (RTS) which are part of the Computer Systems degree offered at the Bachelor Technical School of Computer Systems Engineering at the University of Oviedo, Spain.

The PBL methodology has traditionally been used in higher education, mostly in medical training, and has proof to be a very powerful contextual, collaborative and constructivist learning model [3]. The PBL methodology [4] allows posing a complex problem, which requires integration of knowledge, before learning [5]. Following this methodology, the students are able to discover that in order to solve the problem they first need to acquire new knowledge. However, an eye must be kept on PBL detractor's arguments which suggest that students taking courses based on PBL model show potentially significant gaps in their cognitive knowledge base and do not demonstrate expert reasoning patterns [6].

A blended learning model was adopted by both courses in order to get the best from PBL and minimize its drawbacks. On one hand, PBL was selected as the learning methodology for the hands-on laboratory classes, so the students were able to develop their constructive, self-directed, and collaborative capabilities. On the other hand, a more classical learning methodology was maintained for the theoretical classes, thus assuring that the students developed their cognitive knowledge base and expert reasoning skills. Besides, an innovation was introduced to the PBL methodology so multidisciplinary problems solving objective was achieved: both courses shared a common complex assignment by yielding part of their class time for its commissioning, merging together students from both courses at the same laboratory and class time. The professors of both courses collaborated by merging partial objectives into a common global one, and working side by side as tutors or facilitators.

A common assignment was selected as the final evaluation method because implementation of real-time control systems requires, in general, the interaction between different process layers: real-time control of individual systems, real-time coordinated control and supervision. Often, these layers are programmed in different languages and require the use of different tools in order to build the overall system. The inner control loop is usually implemented in a specific hardware, such a microcontroller or a DSP. In these systems, the programming language is usually C or assembler. For this particular project a DSP microcontroller programmed in C was chosen. For the outer control loop, there are many possibilities depending on the particular application. The running platform can be a computer, an embedded system or a PLC. The platform requirements at this level are related to the need of communication with both the inner control loop and the supervision layer and to the tasks synchronization. A common used language for fulfill this requirements is Ada [7], [8]. Finally, the supervision layer is usually implemented in a language allowing designing the graphical user interface (GUI) as well as tools for data visualization and storage. Common choices are C++, C# or Java. For the development of this course we have selected C++.

In order to carry out such assignment the students must not only apply the concepts acquired at these subjects, but also using some other knowledge from other courses of the degree. The students need to search for new sources of knowledge, to combine different sources of information, to make use of a wide variety of technologies, to improve their capability of self organizing and self learning and to develop their skill of team working. Each student (or group of students) must reach a milestone before going ahead with the next. One of the evaluation criteria used was to measure how much help from the professor was needed by the student to fulfill each milestone. Every student has to register her/his work progress in a portfolio clipboard [9], which includes: managed sources of information, tasks, achieved goals, acquired knowledge and main difficulties. The new teaching methodology requires a more active role from the student in the learning process. A big effort was invested in carefully explaining the students the new rules: the milestones protocol and the evaluation criteria. By doing so, the students evolved from a tolerance attitude into a proactive participative one, making the experience theirs. At the end of the course, every student was faced a course evaluation form containing questions to measure out their view of the experience. Most of the students found that collaborative assignments help them to improve their skill of solving multidisciplinary problems.

This paper presents a collaborative experience between two courses related to the embedded systems engineering, which aim is to complement engineering student's knowledge acquired at the different degree courses, with the capability of facing complex multidisciplinary problems. PBL is used as the learning methodology for the hands-on classes. The way both courses collaborate and how PBL is extended is explained then. Finally, student's opinion about this experience is analyzed by means of one questionnaire.

II. Courses Description

A. Students

The students can take one or both courses. These two courses are in the third year of the Computer Systems degree. Before these topics, students are supposed to have passed topics in programming methodologies, electronic technology of computers, algorithms, data structures, industrial computing and networks.

One might think that the best learning outcomes will be obtained if all students take both courses, so all of them would have studied the theoretical concepts of both courses before facing the final assignment. But the experience has shown that because of this collaborative model, even in the worse scenario where no student has taken both courses, it produces great benefits, because it allows them to develop their team working skills. The key idea is to set up balanced groups made up of students from both courses. No group must be made up of students taking only one course. Those students that do not take one particular course get its basic concepts by interacting with those that do take it, because they need to understand that part in order to understand the whole picture. It is true that such students are not going to develop their expert reasoning at that particular topics of that course, but still they will get a flavor of them, that will allow them knowing its nature, its application, and its justification, and maybe raise their interest in that field, with little effort.

B. Courses organization

Both courses duration is 4.8 ECTS and are organized as follows. There are four hours every week separated into two lectures of two hours each. During the first bimester, first lecture is on theoretical content and second one a hands-on laboratory. It is worth noticing that even at the theoretical lectures students are in front of the computers. Every key aspect of the systems control or real-time theory is tested using computer simulation. Simulink was used for the systems control part and Ada over Linux for the real-time one. During the second bimester, all four hours are laboratory ones in order to provide the students with enough time to make the final assignment project.

Theoretical contents during the first bimester are headed to make the students learn the basics on real-time and embedded systems, following the timetable shown in Table I.

Course materials are stored in a mediaWiki [10]. The use of a wiki allows to easy share materials needed in both courses as well as materials from other courses taught within the Department.

C. Assessment method

Engineering educators recognize that student's exams, class exercises and homework can effectively measure mastery of facts and formulas. However, these sorts of assessments do not encourage students to develop their analytical capabilities as they do not measure the student's skills to understand and apply what they had learned. Nowadays, industry is demanding engineers with a set of skills that are beyond the knowledge that a student can achieve studying a book. In contrast, projects, allow educators to emphasize "the important role that experience plays in the learning process" [11]. We focus our subjects in problem based learning. Our teaching style combines the lectures and labs with the development of some projects. Usually, the students do not have all the pieces to develop their assignments, but need to search in the additional contents presented in the web page of the subjects, in Internet or other media to achieve their projects. Obviously, a traditional exam is not a valid media to measure the efforts and the learning of the students in the problem based learning. For this purpose, we use a portfolio. "A portfolio is a purposeful collection of student's works that demonstrate their efforts, progress, and achievements in selected areas of the curriculum" [12]. It can include the best works, but also preliminary designs or any artifact that could show the progress of the student. Usually, most of our students focus their efforts in programming instead of thinking or analyzing the best solution. Classical assessment based on exams does not promote the critical thinking. Many times when they do team work their tactics is dividing and joining. Each member of the group focuses in one aspect of the problem. This is not the best approach to team working. By using a portfolio, the students can incorporate the results of their meetings, the changes that they have agreed and how they are learning.

Besides, with the portfolio development, the students can improve their ability on writing technical documents. This is recognized as one of the key aspects needing improvement on the new engineers [13]. Portfolios have also been suggested as a direct source for research into student knowledge [14].

The most difficult aspect of a problem based learning course is determining if the desired goals and objectives have been

TABLE I
COURSES TIMETABLE.

Week	Lectures		Labs	
	SCS	RTS	SCS	RTS
1	Basics on control systems	Introduction to RTS		
2	Introduction to dynamic models and feedback	Languajes for RTS applications: Ada	Matlab/Simulink (I)	Initial programming in Ada
3	Time response	Reliability and error processing	Matlab/Simulink (II)	Fault tolerance programming applications
4	PID control	Concurrency	Analog units	Modular programming
5	Introduction to digital control	Real time programming	DC motor control	Concurrent programming
6	Discrete systems	Low level software programming	Microcontrollers (I)	Lego sumo robot
7	Digital control implementation	Real time sofware design	Microcontrollers (II)	RTS design methodology
8	SCADA basis theory	Real time operating systems	DC motor digital control	Programming a railroad model
9 - 15			SCADA (I)	
			SCADA (II)	
	Final Assigment			

TABLE II
PORTFOLIO EVALUATION.

Portfolio content	Evaluation item			
	writing communication	planning	self-analysis	team work
auto evaluation			X	
laboratory reports	X			
design documents	X		X	X
meetings schedule		X		X

achieved. Student's feedback is used extensively to evaluate the performance of both the teaching staff and the subject. Again, traditional assessment methods reveal as a poor tool to determine the achievement of the objectives. Portfolio is an efficient way to demonstrate the achievement of the skills that are signaled as objectives to the course. Student portfolios are listed as a possible means of assessment under the basic level accreditation criteria according to the Accreditation Board for Engineering and Technology (ABET) "Engineering Criteria 2000."

We are using electronic portfolios in a semi-structured way. Because that is our student's first attempt, we suggested them some minimum elements, thus giving them a template than they can freely improve. The student portfolios, include student goals for learning, works in progress, and reflection on the work and processes. Table II shows how any aspect of the evaluation is reflected in the portfolio information.

The use of the portfolio as the evaluation method has proved to be quite satisfactory. The tasks the students needed to complete has been achieved and the implication of students was high, according to the students response shown later in section V.

III. LECTURES

A. Lectures description

1) Supervision and Control of Systems:

- Basics on Control Systems: Introduction to the problem of control. Through the use of a model that does not incorporate dynamics, the effects of disturbances and open loop/close loop behaviors are explained.
- Introduction to Dynamic Models and Feedback: The model presented in the previous lecture is extended in order to incorporate dynamics. Linear and invariant systems. Lapace transform and impulse response. Effects of dynamics in the velocity control of a vehicle are shown.
- Time response: Analysis of time response when arbitrary input is applied to a system. Convolution integral. Step and ramp response. Systems order. Position control of a vehicle.
- PID control: Impact of controller actions (P,I,D) in the close loop response of a controlled system. Reference tracking and disturbance rejection. Control design for electromechanical systems: Truxal pole cancellation. Formulation and implementation of a speed control for a DC motor.
- Introduction to digital control: Analog control vs Digital control. Additional elements in the control loop for digital control implementation. Signal Sampling: sampling theorem and aliasing effects. A/D conversion. Quantization effects. D/A conversion and PWM.
- Discrete systems: Sequences and discrete systems. Difference equations. Discrete time implementation of integral and differential operations. The discretization problem. Linear and Tustin approximations.
- Digital control implementation: Foundations for using the theoretical concepts in a microcontroller based system. Events driven programming. Interrupts. Program structure for digital control realization.
- Basics on supervisory control and data acquisition (SCADA) applications: data acquisition module, graphical representation of the process, alarm handling, data base module, graphical representation of signals, etc.

2) Real Time Systems:

- Introduction to Real-Time Systems: Description of the characteristics and main properties of RTS.
- Languages for RTS applications; Ada: Description of the desirable characteristics that a RTS programming language must cover.
- Reliability and error processing: Study of the aspects

related to the construction of free error programs and what can be done when errors appear during the program execution. Ada mechanisms for error management are shown. Fault tolerance and exceptions handling.

- Concurrency: Concurrent aspects of the RTS. Tasking. Interprocess communication. Shared memory and programming with Protected Objects in Ada. Interprocess communication and message passing mechanism, rendezvous in Ada. Practical cases solving.
- Real-Time Programming: Time management, programming applications using time functions. Practical cases solving, time-outs, asynchronous transfer control, periodical tasks programming, sporadic tasks programming. Scheduling and time requirements. Solving priority inversion problem. Ada programming facilities to solve all these aspects.
- Low level software programming: Requirements to constructs programs adapted to the characteristics of hardware devices. Interfaces between Ada and C.
- Real time software design: Hrt Hood Methodology. Study of a practical Case.
- Real time operating Systems: Description of the of the desirable characteristics that a RTS Operating System must has. Examples.

B. Labs description

1) Supervision and Control of Systems:

- Matlab/Simulink (I): Introduction to Matlab/Simulink. Implementation of a velocity control for a vehicle without dynamics. Comparison between open loop and close loop control strategies.
- Matlab/Simulink (II): Transfer functions in simulink. Import of model parameters and export results from/to Matlab. Implementation of a velocity control for a vehicle incorporating dynamics.
- Analog units: (Fig. 1). Time response of first and second order dynamic systems by using analog electronic circuits. Measurement of electrical variables using a digital scope. Measurement of system properties such a settle time, peak value, overshoot and final value.
- DC Motor Control: (Fig. 2). Control of a DC machine using analog units and *Feedback*® mechanical unit. Current control, velocity control and position control. Relation between the electrical variables (armature current) and mechanical variables (speed/position). Selection of controller's gains an impact on the control dynamics.
- Microcontrollers (I): DSPic 30F6010 features. Introduction to MPLAB. Configuration of I/O ports, Timers and AD converter. Using the simulator for testing purposes.
- Microcontrollers (II): Configuration of PWM and motor PWM modules. Serial communications. Interface between Matlab and the DSPic.
- DC motor digital control: (Fig. 3). Implementation of a speed control for a DC motor using the DSPic 30F6010. A low level library for programming the dspPIC has been developed by our own, so making possible for the students to focus on the control problem instead on the digital system hardware configuration.

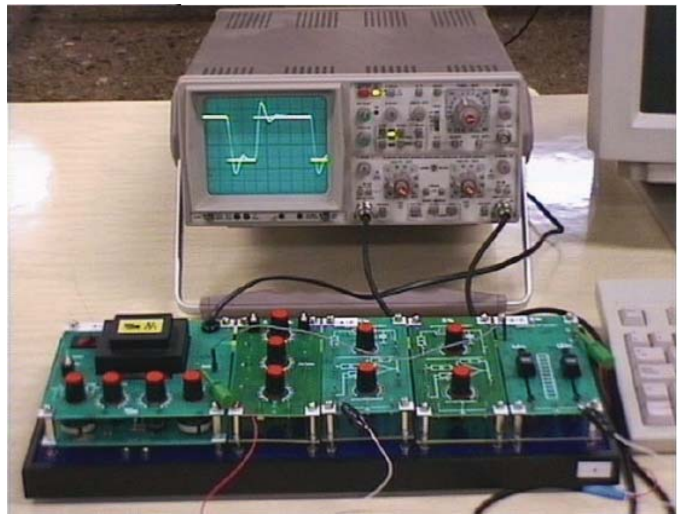


Fig. 1. Analog units for system response measurement.

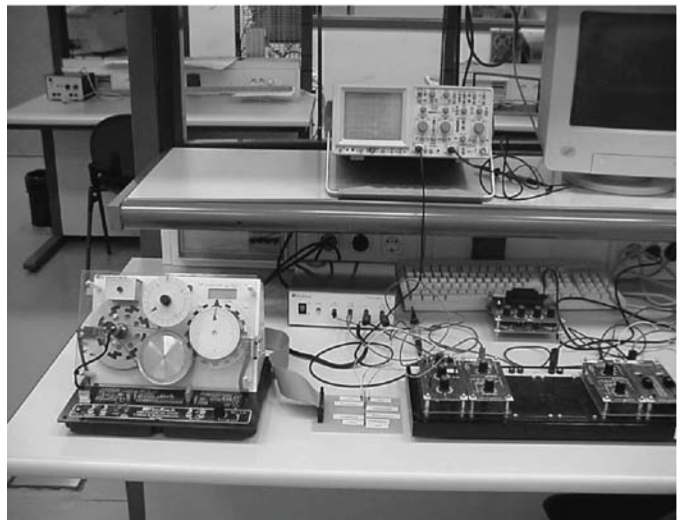


Fig. 2. *Feedback*® mechanical unit educational system for the control of a DC motor.

- SCADA (I): Design and implementation of the skeleton of the data acquisition module using the publication/subscription paradigm. TCP/IP technology is used to implement the communications to the Ada control layer.
- SCADA (II): Design and implementation of the skeleton of the graphical interface of the system that allows following the evolution of the robot.

2) Real Time Systems:

- Initial programming in Ada: Basic structures and data types to implement and Ada program. Modular decomposition.
- Fault tolerance programming applications.
- Modular programming. Generic Units and package.
- Concurrent Programming. Tasks creation. Solving synchronization problems.
- RTS Design Methodology. Using Stood to create a model to solve a RTS problem .
- Lego Sumo robot (Fig. 4(a)): Construction and programming of a Lego boot using Ada. This is a team

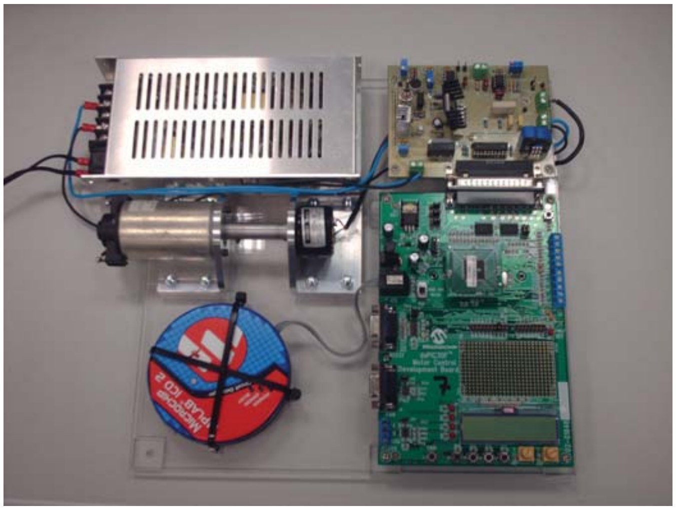


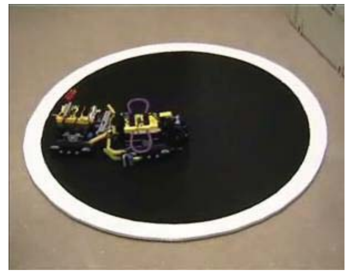
Fig. 3. dspPIC an custom board for the control of a DC motor.

work where the students have to build their own sumo bot, searching information on the net and books, and programming them using an Ada Compiler developed by [7]. With Lego RCX is easy to construct a robot, including different sensors and motors without electrical or mechanical knowledge. This set is frequently chosen for its low cost and ease of use. However, most of the work being done with it is in teaching reactive robotic architectures, [15], [16]. As the robot is a sumo bot, its behavior depends of its rival and also on the limits of the fight pitch. In this team work students must write their portfolio to collect their advances and decisions in order to improve the original design. After a first combat they have an opportunity to re-design their bot for a new combat.

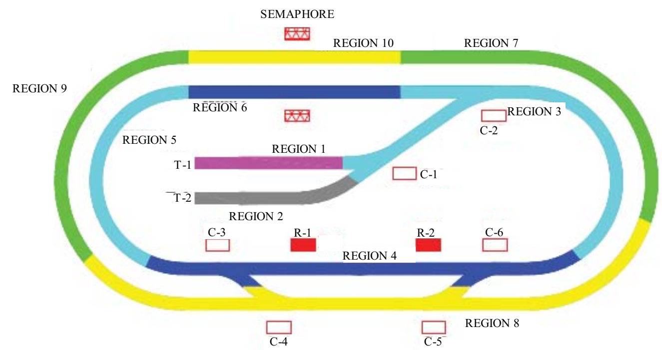
- Programming a railroad model (Fig. 4(b)): Using simulators is many times perceived as a poor experience by students due to the fact that they are only using software instead of a real plant. A richer experience is achieved when is possible to use a physical model. Model railroads provide a wealth of problems from both the discrete and continuous real-time domains. The electronics are easily understood by most undergraduate computer science students. Students are highly enthusiastic about writing software to control a model train layout [8]. We have a simple railroad with two concentric ovals and the tracks to change from one to another. Train's reference position is obtained through two cameras and a computer that process images. The team must control the movement of two trains so they follow a pre-defined trajectory with no collisions and as quick as possible. The team work must collect results at their portfolio.

IV. Final Assignment

In order to practice the learned knowledge, students are faced to a final laboratory project at the end of the semester. In this project, students work together in groups of two or three people. The main idea of the project is to force



(a)



(b)

Fig. 4. RTS labs. a) Lego Sumo robot, b) Railroad model.

the students to discover that using the previous acquired knowledge is possible to solve more complicated problems. Besides, the students need to make use of formerly acquired knowledge and technologies such as: TCP/IP communications, C++ programming, data bases, RS-232 serial communications, graphics plotting, and using a professional development suite, in this case Microsoft®Visual Studio .Net or CodeGear® Builder. Each group of students programmed the whole system and made a presentation of the work during the last lesson.

Robotics, and in particular mobile robots, is an attractive platform where the students can put in practice the topics of the course [17]. A two steering wheel mobile robot was selected as the target platform for the collaborative assignment [18]. We used several platforms and tools to integrate the different process layers described before: real-time control of DC motors (implemented in a DSPic), real-time coordinated control (last course implemented in a PC but moving to an embedded system –TS-7250 from Technologic systems®– platform running an ARM processor in the next course) and supervision (remote PC).

For the proposed problem, a hardware platform has been designed by our own. Schematic representation of the designed platform is shown in Fig. 5. As shown, two of the wheels are manned by a DC motor, each of one driven by a H-bridge module connected to the PWM outputs of a DSP microcontroller (*Microchip® dsPIC30F610*). The angular velocity of the machine is measured using a speed sensor connected to the axis of the machine. The setup for the simulation of each wheel is shown in Fig. 3.

The inner control loops are responsible of controlling the angular velocity of each machine by means of a PI controller. Both DSP's are connected through a RS-232 interface to a

TABLE III
ASSESTMENT SKILLS.

Mobile robot tasks	Skills				
	control design	communications	supervision	Ada programming	microcontrollers
Control of DC Motor	X				X
Trajectory Tracking	X			X	
User input and feedback			X		
Subsystems interface		X	X	X	X

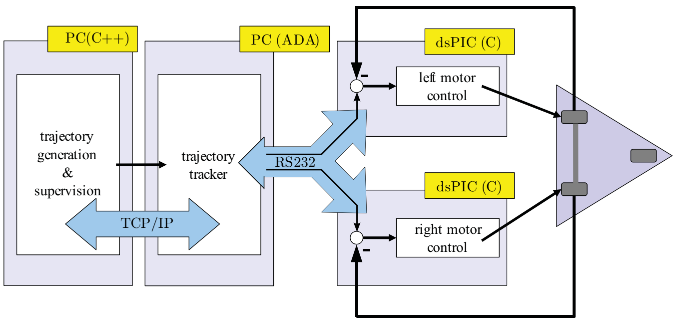


Fig. 5. Schematic for the designed platform.

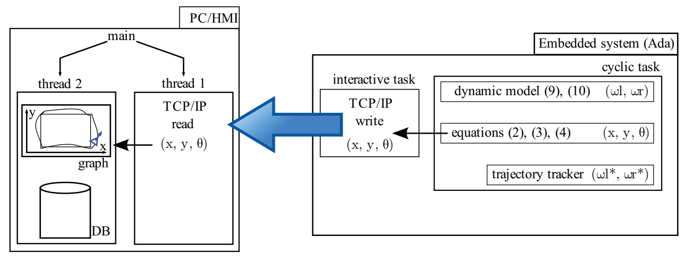


Fig. 6. Simplified logic diagram for the first stage of the final project.

TABLE IV
SKILLS LEARNING.

	SCS	RTS	PBL
control design	X		
communications		X	X
supervision	X		
Ada programming		X	
microcontrollers	X		

PC running the higher level real-time control algorithm. This control layer is implemented in Ada and its objective is to generate the velocity commands so the robot is able to track the desired trajectory. In addition, the Ada program must communicate with the supervision layer though a TCP socket interface. The supervision layer implements the interface to the process. It includes the GUI that allows the user to select the desired trajectory to follow from a base of trajectories. It also represents the reference trajectory and the actual one. It provides storage capabilities for generated data and for the representative values of the state of the process. Relation between needed skills and assessment main tasks as well as the course where the needed skills are learnt are shown in Tables III and IV, respectively.

A. Assignment development

The first PC (PC/HMI) is running the supervision application. The application runs two different tasks implemented using threads. The main thread is the responsible of attending the GUI events, painting in the screen the output of the process and storing the results in a database. The second thread, is executing the communication task. Communication is implemented using a TCP/IP socket, being the supervision PC the client. Although the students decided what was the information needed in order to track the process, a recommendation was made to receive at least the variables containing the robot position, (x, y, θ).

The second PC was running the outer control loop, programmed in Ada. The PC was equipped and configured with the needed Ada tools. The application was executing also two different tasks. The main task, responsible of the generation of the velocity commands to the two wheels, was implemented as a cyclic task. The sample time was established to $10ms$. The actions programmed in this task were as follows: 1) read from the two RS-232 interfaces –one for each microcontroller– the actual wheels velocities, 2) using the equations described in section IV-B, calculate the actual velocity and position of the vehicle, 3) compute the new velocity commands for the wheels and, 4) write the commands to each RS-232 interface. The second task, running in the idle time, was attending the communication with the supervision PC. Communication was implemented using TCP/IP sockets and the Ada PC was configured as the server. The data sent to the client was the estimated position of the robot.

Finally, each microcontroller was running the inner control loop. This control loop was asserting that the motor velocity was following the command. Sample time for the control was set to $1ms$. Control loop was implemented in the interrupt service routine of the A/D converter. Actions taken in the routine were as follows: 1) read velocity from the velocity sensor, 2) take the reference received from the Ada through the RS-232, 3) calculate the new control action –voltage– as the output of the PI regulator, 4) update the PWM and, 4) write the measured velocity to the RS-232 interface.

B. System modeling and algorithm description

During the theoretical lessons on control theory within the SCS topic, the students are headed to the objective of designing a close-loop control for the mobile robot. Using *Simulink*®, the dynamic model of the system is explained, built and simulated. The proposed dynamic model has been taken from [18] as shown in Fig. 8. For the implementation of the control, a simplified version neglecting the feedforward decoupling mechanism shown in [18] has been implemented.

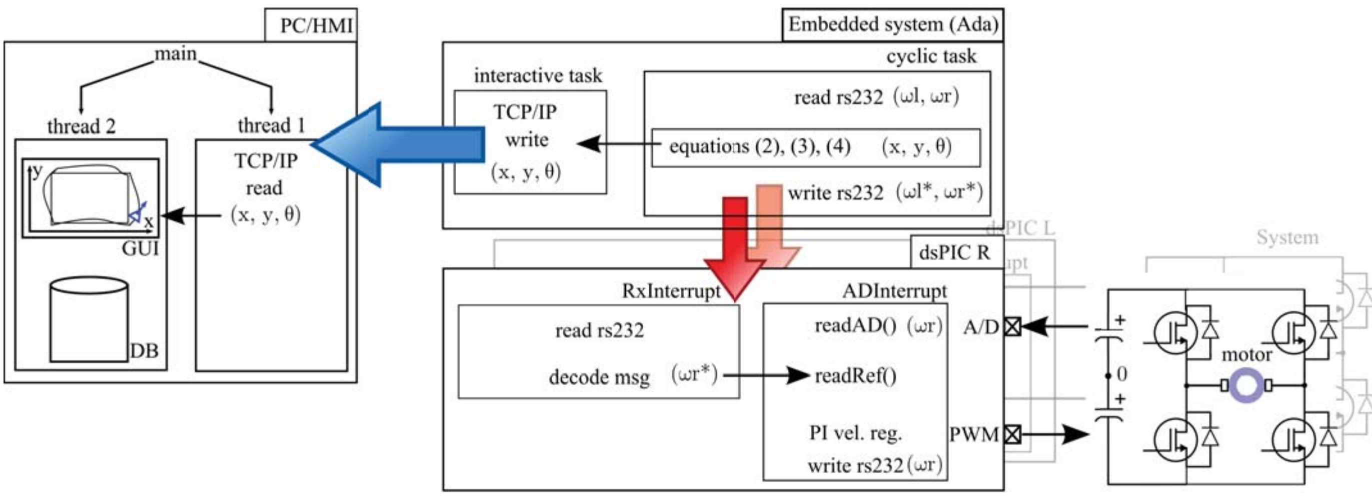


Fig. 7. Logical diagram of the final assignment. It shows the three systems interaction as well as key processes running on each system. For the sake of simplicity, only one microcontroller is shown in the top layer of the diagram.

From here, the complete model equations are described. The derived equations are provided to the students along with the aforementioned paper [18], so they can focus on the implementation details. In the subsequent subsections, first the cinematic and dynamic model of the vehicle are explained and second the implementation of a trajectory tracker is explained.

1) Dynamic model: Dynamic model is explained though the decomposition into three different models: steering cinematic model, vehicle cinematic model and vehicle dynamic model.

a) Steering system cinematic model: Cinematic model of the steering system allows obtaining linear and angular velocity of the vehicle from angular velocities of the wheels, as shown in (1).

$$\begin{bmatrix} v \\ w \end{bmatrix} = \begin{bmatrix} \frac{R_R}{2} & \frac{R_L}{2} \\ \frac{R_R}{T} & \frac{-R_L}{T} \end{bmatrix} \begin{bmatrix} \omega_R \\ \omega_L \end{bmatrix} \tag{1}$$

where, R_x and ω_x are the wheel radius and the angular velocity of wheel x respectively and T the vehicle wheelbase.

b) Vehicle cinematic model: Vehicle's cinematic model relates linear and angular velocity with vehicle position in a 2D space. It is worth noticing that vehicle position is given not only by (x, y) coordinates but it is needs to include a third component for the robot orientation (heading), so (x, y, θ) is the full state. Relations are shown in (2), (3) and (4)

$$\theta_{(t)} = \int_0^t \omega_{(t)} dt \tag{2}$$

$$x_{(t)} = \int_0^t v_{(t)} \cos \theta_{(t)} dt \tag{3}$$

$$y_{(t)} = \int_0^t v_{(t)} \sin \theta_{(t)} dt \tag{4}$$

c) Vehicle dynamic model: The dynamic model of the system allows relating the generated forces –dc motors torque– with the change in the actual position. This model is used in the simulator in order to allow isolate testing of each block in the project. A diagram for the dynamic model is shown in Fig. 8. For the proposed model, and using Newton's second law of dynamics, is possible to simulate the reaction of the vehicle to changes in the torque reference to the motors, as shown in (5) y (6)

$$\sum F = ma = m\frac{dv}{dt} \tag{5}$$

$$\sum \tau = J\alpha = J\frac{d\omega}{dt} \tag{6}$$

Using the equations from the steering cinematic model:

$$v = \frac{R}{2}(\omega_R + \omega_L) \Rightarrow \frac{dv}{dt} = \frac{R}{2}\left(\frac{d\omega_R}{dt} + \frac{d\omega_L}{dt}\right) \tag{7}$$

$$\omega = \frac{R}{T}(\omega_R - \omega_L) \Rightarrow \frac{d\omega}{dt} = \frac{R}{T}\left(\frac{d\omega_R}{dt} - \frac{d\omega_L}{dt}\right) \tag{8}$$

where wheel's radius has been assumed to be the same and equal to R for the sake of simplification.

By algebraic manipulation, and following reference [18], expressions (9) and (10) are obtained.

$$\tau_{MR} = A\frac{d\omega_R}{dt} + C\frac{d\omega_L}{dt} + E\omega_R \tag{9}$$

$$\tau_{ML} = B\frac{d\omega_L}{dt} + D\frac{d\omega_R}{dt} + F\omega_L \tag{10}$$

where,

$$A = \frac{1}{g_R}\left(g_R^2 J_{MR} + J_R + \frac{R_R^2}{2}\left(\frac{M}{2} + \frac{J}{T^2}\right)\right)$$

$$B = \frac{1}{g_R}\left(g_L^2 J_{ML} + J_L + \frac{R_L^2}{2}\left(\frac{M}{2} + \frac{J}{T^2}\right)\right)$$

$$C = \frac{1}{g_R}\left(\frac{R_R R_L}{2}\left(\frac{M}{2} - \frac{J}{T^2}\right)\right)$$

$$D = \frac{1}{g_L}\left(\frac{R_R R_L}{2}\left(\frac{M}{2} - \frac{J}{T^2}\right)\right)$$

$$E = \frac{1}{g_R} b_R$$

$$F = \frac{1}{g_L} b_L$$

2) Trajectory tracker: Trajectory tracker module's main objective is to generate commands for the velocity control loop of the motors driving the wheels. At each sample time, available information is the desired trajectory selected at the supervision layer and actual position estimation. Then, the trajectory tracker needs to implement an algorithm allowing the following transformation:

$$[\omega^*_{r,}\omega^*_l] = f\left(x^*, y^*, x, y\right)$$

where x^*, y^* are the coordinates of the commanded trajectory, x, y estimated actual position and $\omega^*_{r,}\omega^*_l$ velocity commands to each motor.

As explained before, implementation of the trajectory tracker is made in Ada language. The module communicates with the inner control loop through the serial port. In addition, it has to receive the precalculate trajectory from the supervision layer. This communication is done by TCP sockets.

The algorithm to generate velocity commands is based on the cinematic model of the vehicle and in the measurements given by the velocity sensors at each motor.

3) Algorithm description: Mobile position in x, y plane (the movement is constricted to this plane) is determined by the estimated system state (x, y, θ), where x is the projection in the x axis, y the projection on the y one and θ robot heading. Comparison between commanded position (x^*, y^*) and estimated one (x, y) from the cinematic model, allows to generate velocity commands. Because the given trajectory does not include heading command –θ^*–, first step is to know if given the actual position and the reference, a change in the robot heading is needed in order to reach the next point of the desired trajectory. Heading command is calculated as (11):

$$\theta^*_{[k]} = atan\frac{y^*_{[k]} - y_{[k]}}{x^*_{[k]} - x_{[k]}} \tag{11}$$

Once heading command has been obtained, it is already possible to get linear and angular velocity commands using the discrete derivatives by Tustin approximation from the cinematic model of the vehicle (12) to (14).

$$\omega^*_{[k]} = 2\frac{\theta^*_{[k]} - \theta_{[k]}}{T_s} - \omega^*_{[k-1]} \tag{12}$$

$$v^*_{x[k]} = 2\frac{x^*_{[k]} - x_{[k]}}{T_s} - v^*_{x[k-1]} \tag{13}$$

$$v^*_{y[k]} = 2\frac{y^*_{[k]} - y_{[k]}}{T_s} - v^*_{y[k-1]} \tag{14}$$

$$v^*_{[k]} = \sqrt{{v^*_{x[k]}}^2 + {v^*_{y[k]}}^2} \tag{15}$$

where T_s is the sample time.

From linear and angular velocity commands v^* and ω^*, references to the inner velocity control loop ω^*_r and ω^*_l, are obtained from the inverse cinematic model of the steering system (16)

$$\begin{bmatrix} \omega_{rR} \\ \omega_{rL} \end{bmatrix} = \begin{bmatrix} \frac{1}{R_{rR}} & \frac{T}{2R_{rR}} \\ \frac{1}{R_{rL}} & -\frac{T}{2R_{rL}} \end{bmatrix} \begin{bmatrix} v \\ \omega \end{bmatrix} \tag{16}$$

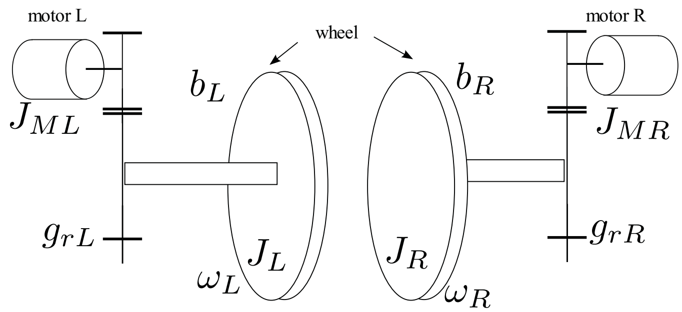


Fig. 8. Mechanical model for the two steering wheel mobile robot.

V. Students Response

Student's opinion about the presented courses has been obtained through the use of one questionnaire. The questionnaires were fulfilled by the students after the final assignment presentation was done and before the evaluation results were issued. The questions about the collaboration of both courses is shown in Table V.

All the students agreed that it has been a good experience. It is worth noticing that lower marks are in the questions related to the effort required to pass the courses as well as to the materials. About this last question, we are working on improving both the materials for the hands-on laboratories and also the documentation in the web page. The experience taught us that the question about the course difficulty is related to how easy the information needed to complete the project can be found. Therefore, we think this mark can also be raised with more documentation about some specific problems they encounter. In order to avoid returning to the previous teaching method, where all the materials were immediately available to the students, we will keep the information filtered. It will be shown to the students in fragments, and only after assuring that they have searched the information by their own.

Additionally, in order to avoid tendency of the students to delay the tasks until the last weeks of the course, more milestones are going to be established during the first bimester. This will help to minimize the overload sensation because of too much effort concentrated in the last weeks.

Finally, taking into account that this is the first year of the experience, we think the results are quite satisfactory.

VI. Conclusions

This paper has presented a collaborative experience between two courses related to the embedded systems engineering. A blended learning mode has been applied. PBL has been used as the learning methodology for the hands-on classes, and

TABLE V
STUDENTS RESPONSE QUESTIONNAIRE. MARKS RANGE IS FROM 0 TO 5.

Question	Result	
I think...	mean	std
...it has been important for my curriculum.	4,13	0,64
...it is positive to make common assignments.	4,63	0,52
...it is positive to blend different topics in the same assignment.	4,75	0,46
...the effort needed to pass the courses is adequate.	3,5	0,53
...the materials are appropriated.	3,63	0,52
...the common assignment is challenging and motivating.	4,63	0,74

a more traditional teaching for the lectures. Description on the evaluation method using a portfolio has been extensively explained. Common final assignment design as well as implementation details have been included. Students opinions about the experience has been reported and analyzed by means of one questionnaire.

Results demonstrate that the experience is positive for the develop of reasoning, critical thinking and use of acquired knowledge. This is an agreement with other authors [19], who conclude that the successful completion of an embedded design gives the student a sense of achievement which is lacking in more conventional engineering courses.

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Wireless4x4: an integrating learning experience for Telecommunications students

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Abstract—**The Telecommunications Engineering degree contains the study and understanding of a wide variety of knowledge areas, like signal theory and communications, computer networks or radio propagation. This diversity of fields makes it hard for the students to integrate all these knowledge, which in turns results essential to tackle real and practical problems that involve different subjects. As a response to this need of integration, in University Rey Juan Carlos an educational project based on Problem Based Learning (PBL), called the Wireles4x4 Project, has been carried out. In this project, groups of students build a complete system that is able to autonomously drive a radio controlled car, involving different technologies such as wireless communications, positioning systems, power management or system integration. The objectives of this educational project are: (1) The development of an active learning methodology, by which the students acquire integrated knowledge and skills on a variety of subjects; (2) The acquisition of professional skills like teamwork capabilities, oral and written communication, and long term task scheduling; (3) The participation of the students in an interdisciplinary engineering project with time and budgetary constraints. The results show that the participating students improve not only their specific knowledge on the involved issues, but also their capability of integrating different subjects of the degree and the skills for autonomous learning.)**

Keywords: integrating learning; problem based learning; professional capabilites training; telecommunication engineering.

I. Introduction

The Wireless4x4 project is an annual educative project developed by students and educators at Universidad Rey Juan Carlos, in Fuenlabrada, Spain. Specifically, the participants of this learning experience are members of the Telecommunication Faculty (ETSIT, from its Spanish name *Escuela Técnica Superior de Ingeniería de Telecomunicación*), in which three five years degrees and one six years degree are offered, all of them closely related with information technologies.

Each of these degrees contains the study of a wide variety of knowledge areas and professional skills, like signal theory, communications theory and practice, electromagnetic fields and radio propagation, computer networks, data processing, programming fundamentals or electronic design. Along its five or six years, the students follow a plethora of different courses which sometimes are not conceptually connected. Therefore, it is often hard for the students to integrate all this knowledge and skills, which is itself an essential capability that a telecommunication engineer is expected to apply in his professional career. Moreover, the professional market requires engineers that not only manage different technical knowledge and skills, but also are used to face with real problems with real constraints and are able to work in teams, organize a long-term work and make public presentation of their results with clarity and determination. All of these professional skills are hardly acquired with the classical learning methodology.

Therefore, the Wireless4x4 is an innovative learning experience, based on Problem Based Learning (PBL) techniques [1], [2], which represents an effort of Universidad Rey Juan Carlos to overcome these limitations of the conventional educative procedures. Then, the main objectives of the project are:

- The development of an active learning methodology, by which the students acquire integrated knowledge and skills on a variety of subjects.
- The acquisition of professional skills like teamwork capabilities, oral and written communication, and long term task scheduling.
- The students' involvement in an interdisciplinary engineering project with real time and budgetary constraints.

The project is organized as an extra course, recognized as a sixty hours course. Moreover, the students' designs are tested in a final public competition, which is a race in a pre-set circuit in the ESTIT campus. The best design is awarded with a prize for all the members of the winner group, like PDAs or laptops. The participants of this project are students of each of the degrees of the ETSIT, who are in their third or higher year. This constraint is necessary to count on the participation of students with a minimal base of knowledge on communication systems, electronics and programming. Before the final exams in June, the following year project is presented in the classrooms and with posters, in order to motivate the participation of the students.

The students participate in groups of three members, which during these years has shown to be an appropriate number to develop all the tasks, while avoiding the problem of having parasite students in the project. Because of resources constraints, the project can hold three groups (this year has grown up to four) per year, so among the candidate groups (this

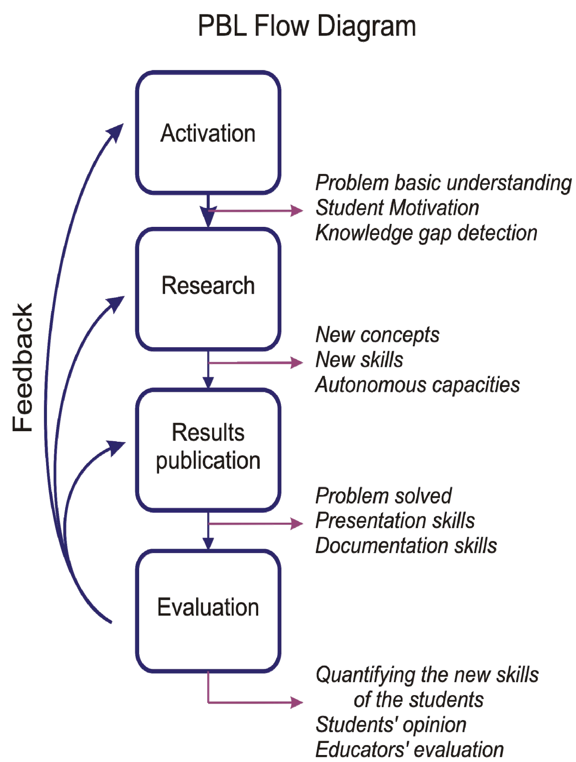

Figure 1. A typical PBL diagram with four phases and the expected results for each phase.

year there were six) a selection procedure is carried out, which is in turn a first step in the motivation-activation phase of the PBL project.

From a technical perspective, in this project the groups of students build a complete system that is able to autonomously drive a radio-controlled car. The control of the vehicle trajectory is carried out by an autonomous algorithm, that is executed by a control computer away from the vehicle, using the GPS (*Global Positioning System*) coordinates obtained by an on board computer.

The on board computer is also capable of controlling the servomotors which controls the speed and direction of the vehicle. A WiFi network performs the communication between control and on board computers. The power of the on board system is provided by a common battery, so a power management system is also implemented. Then, different knowledge and skills related to signal processing, positioning algorithms, wireless communications, electronic, programming and system integration are needed to complete the Wireless4x4 project.

The remain of the paper is organized as follows. In Section II, a brief introduction to PBL methodology and phases is provided. Then, the learning methodology and the project description are described in depth in Section III. The results of the three-fold evaluation procedure are given in Section IV, and in Section V the main conclusions of this experience are drawn.

II. Problem Based Learning

According to H. S. Barrows [3], the father of the PBL methodology, problem based learning is "a learning method based on the principle of using problems as a starting point for the acquisition and integration of new knowledge". In general, the student's learning process is stimulated with a problem, and for solving the problem, the student discover what to learn and how to do it. The main function of the problem is, then, to motivate the learning process. At the end of this process, the students not only has acquired a set of skills and competences, but also has learned how to autonomously acquire new ones [4], [5].

On the one hand, the main advantages of this active methodology is that the students learn very important professional skills, like how to search information, solve problems, work in teams and build new knowledge. Moreover, the students are demanded to deeply investigate the subject of the problem, not only to learn basic theoretical concepts. On the other hand, the main drawback of this learning approach is that it requires more time to cover the same amount of knowledge than a classical approach. Moreover, the cost of this kind of learning experiences is higher, and the number of students in each group needs to be reduced. However, with more reduced and realistic syllabus, and the help of information technologies these drawbacks tend to be minimized.

Figure 1 represents a general flow diagram of the four main stages of a problem based learning procedure [6]. Firstly, a motivation phase is needed for activating the previous knowledge about the subject, define the new knowledge that the students will need to acquire, preparing a scheme to deal with the problem, and properly motivating the students. Secondly, in the research phase the students autonomously search, filter and interpret the information needed for solving the problem. Then, in the third phase, the solution is documented and published.

Finally, the very important evaluation phase is critical for the improvement of the educative project. This evaluation phase should contain objective criteria and subjective opinions from both the students group and the participating educators. Since this project is repeated each year, the feedback from this stage to the previous ones is needed to modify the planning for the future.

III. Methodology

In this section we describe the Wireless4x4 project using a two-fold approach. Firstly, we emphasize the learning methodology as a particular case of the general four-stage scheme presented in Section II. Secondly, a description of the project is presented to clarify one of the main aspects of this experience, which consists of the integration of knowledge from different subjects of the telecommunication degree.

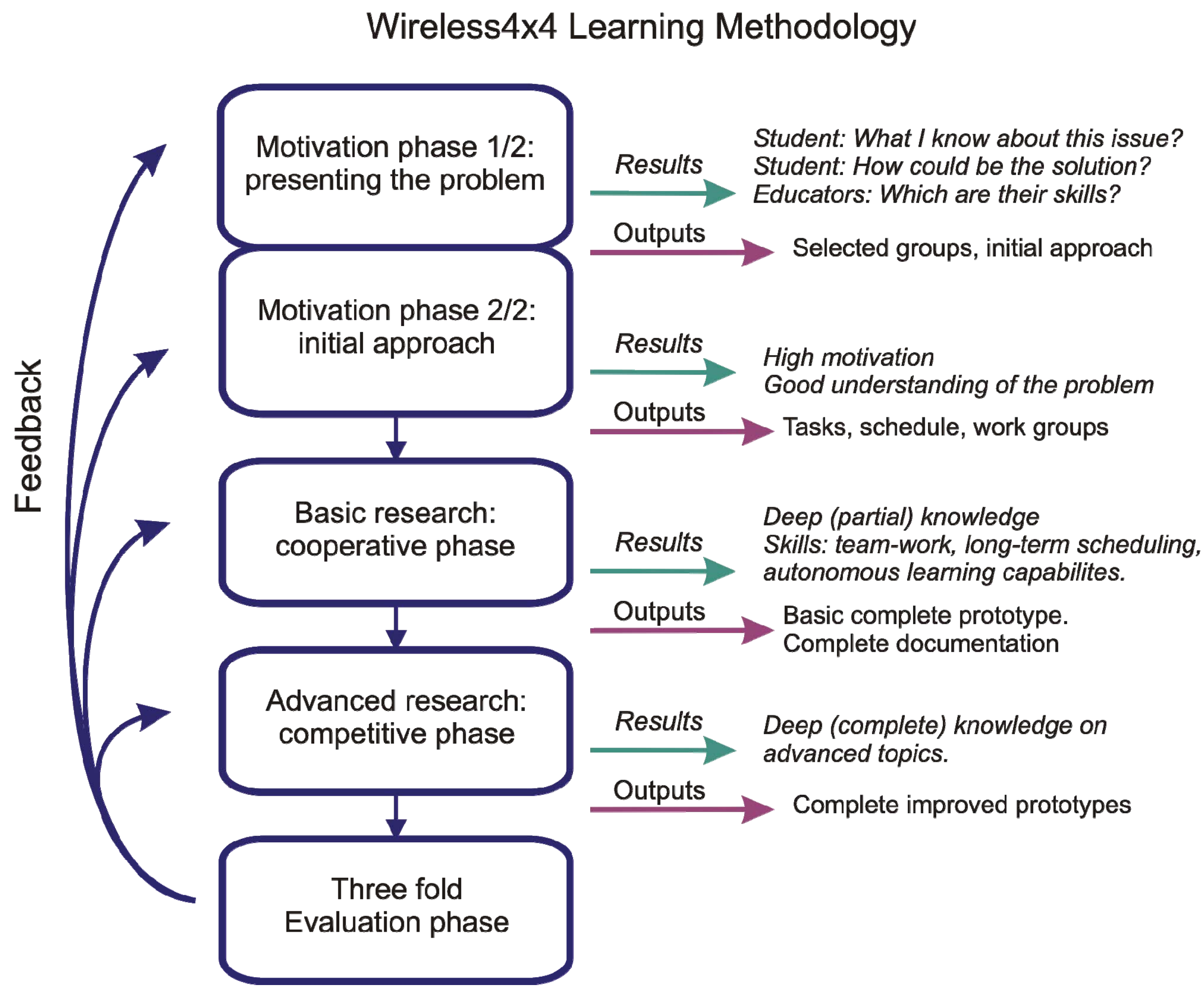

Figure 2. Wireless4x4 learninng methology: flow diagram with the expected results and the objective outputs of each phase.

A. *Learning Methodology*

Figure 2 represents the learning methodology of the Wireless4x4 project. Four phases are used (the first one being divided in other two). The expected results of each phase and the objective outputs (products, documentation, indicators) are also shown.

1) Motivation phase.

The main two ideas of this project are that the students develop an autonomous learning effort for solving a real life problem and that they acquire a integrating perspective of different technologies involved in that problem. For this purpose, it is essential that the students are motivated enough to face inherent difficulties of those both ideas. To accomplish this, in the motivation phase the students participate in a group interview in which only the best and most motivated groups are selected for the experience. In the selection procedure, both the students' records and the motivation of the group are taken into account. Furthermore, in this first interview, a global perspective of the problem is provided, and the students are requested to design a solution during fifteen minutes with the help of a computer connected to the Internet. This way, three objectives are attained. Firstly, the students discover what they know about the problem and the main gaps they have to cover for fulfilling the task. Secondly, they begin to feel curiosity about what could be the best solution. Thirdly, the educators gets a global perspective about the qualification of each group, which, in turn, on the one hand helps in the selection procedure and on the other hand underline which knowledge and skills should be learned by the students in the following phase. This is also the first evaluation point of the project. The result of this first part of the motivation phase is therefor a selected set of participating groups and a base of motivation for all the participants.

In the second part of the motivation phase, the problem is described in detail, and a first approach of the solution is investigated. For this purpose, a group session involving all the selected participants and the educators is carried out. In this session, the educators present the problem and the time, resources and cost constraints. Also, a previous simplified version of the project is shown to the students. Then, using a brainstorming approach, the general solution is investigated by the students. The output of this phase is a design of the different parts that are involved in the project, and an assignment of the tasks of each part to a different group. Also in this session, the initial groups are interleaved, according to the preferences of the students and the difficulty of each task. The result of this phase is that each student is highly motivated to try to complete his task, since they have selected it and they know that the whole project depends on each single participant.

2) Basic research and resolution phase

After the motivation phase, the interleaved groups start the second block of the project, which is the basic research and resolution phase. In the session described above, each of these groups was assigned a particular task. Moreover, all the students and the educators know the main gaps that the groups have in their knowledge and skills. Therefore, in this phase each group carries out a deep research in its own part of the project, propose a solution for the specific sub-problem, design it with the appropriate tools, implement the solution, test it, and prepare a detailed documentation. The main task of the educators in this phase is to lead each group with suggestions about how to find the solution, provide the students with the necessary tools, and supervise that each task can be completed on time. Finally, all the groups incorporate their respective parts of the solution to a common platform, thus building a first basic solution for the whole system. Moreover, in an intermediate group session, each group presents its solution to the rest of the groups. This is the intermediate evaluation point of the project. The result of this phase is that each member of each of the initial groups has acquired a deep knowledge of a part of the project, but adding all the expertise of each of its components, each group has a full vision of the final solution.

3) Advanced research and resolution phase

This intermediate group session is also the starting point for third block of the project, the advanced research and resolution phase. Here, the initial groups are restored and their main objective is to improve the basic solution implemented in the cooperative previous phase in order to improve their final prototype. For this purpose, each group will propose an improvement to the educators, who will lead them to find the information needed for its development. In this phase each group gets an advanced expertise about one or more particular issues related, for example, to control theory, location algorithms, electronics or signal processing. The output of this block is a finished prototype for each group. The result is that, within each group the knowledge of the previous phase has been shared, and knew knowledge and skills have been acquired by all of its members.

Finally, a competition among all the groups is organized. The main objectives of this phase are to evaluate each one of the final solutions found by each group and to develop an interesting marketing task for the next year project among possible new participants. This is the final evaluation point of the project. Moreover, this competition and the prizes are part of the initial motivation for the students.

4) Evaluation

The project has a three-fold evaluation. Firstly, an evaluation of the technical knowledge and professional skills acquired by the students is made using the results of the three evaluation points (initial, intermediate and final) described above. Secondly, a survey of the students' opinion was carried out, investigating the main aspects of the project, that is: its interdisciplinary content, the practical approach used, and the general methodology (see Section IV for details). Thirdly, a final evaluation was made among the participating educators, related to the educational aspects of the project and the workload.

B. Project Description

The Wireless4x4 project follows a practical and integrated approach of several knowledge areas that are tackled in different subjects of the ETSIT degrees. The project is based on PBL methodology and hence the students are responsible to acquire the knowledge and skills needed for the achievement of the objectives and requirements described at the beginning of the project. Moreover, the students must face the technological, time and budgetary constraints that are typical in engineering projects.

The final aim of the Wireless4x4 project is the design, implementation, test and demonstration of a complete communication system that is able to autonomously drive a radio controlled car. The control of the vehicle trajectory must be carried out by an autonomous algorithm, which is executed by a control computer away from the vehicle, using the GPS coordinates obtained by an on board computer. A WiFi (IEEE 802.11b) network performs the communication between the control and on board computers. Hence, the knowledge areas involved in the project are:

- Analog circuit design and implementation: for the on board power supply system.
- Digital communications: for the implementation of the WiFi network.
- Embedded software and hardware systems integration and configuration: for the design and implementation of the hardware and software platform.
- Signal processing and control theory: for the implementation of the autonomous driving algorithm based on the GPS information.
- Software development: for the implementation of JAVA programs running in both control and on board computers.

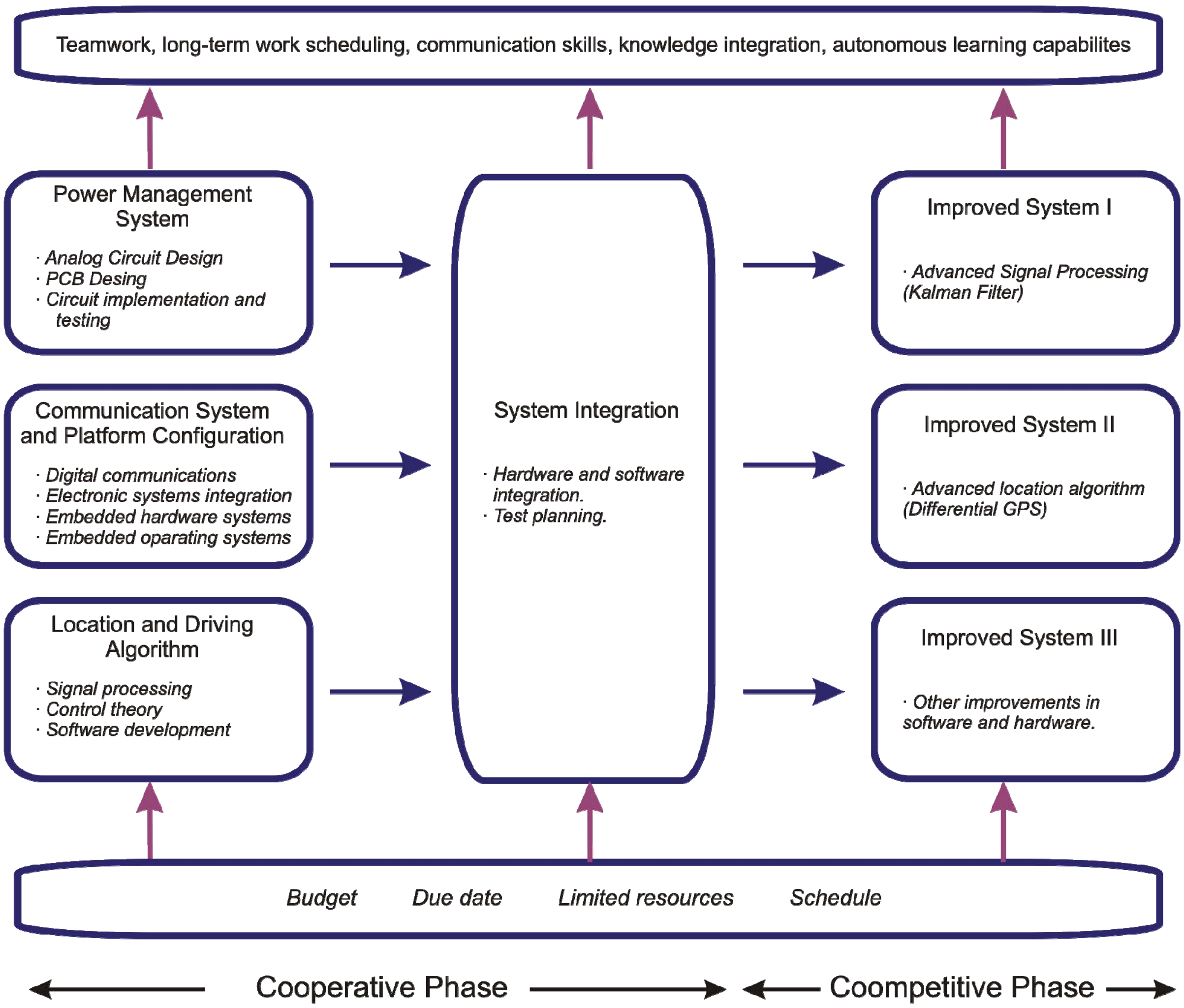

Figure 3. Wireless4x4 learninng methology: flow diagram with the expected results and the objective outputs of each phase.

- System integration: for the integration of hardware and subsystems to complete the whole system.

The students should be able to relate the concepts from these knowledge areas and to adapt them for solving the real problem considered in this project. At the end of the project, each group of students will have to build a fully functional prototype, within the proposed deadline, and to participate in the race against the rest of groups. Therefore, the student faces a realistic environment with task deadlines, budgetary constraints and limited resources, all of them shown in Figure 3 as lower inputs of the process. Moreover, as shown in that figure, the Wireless4x4 project is divided in two phases, cooperative phase and competitive phase, corresponding with basic research and advanced research phases, respectively. Now we describe the particular tasks that the groups must carry out in these two phases.

1) Cooperative Phase

As explained above, there are several areas of knowledge involved in the project. Thus, the students have to face up a hard initial learning curve in the first months of the project development. Hence, in this initial phase, the three groups cooperate in order to reach a common target: the construction of a basic prototype of the radio controlled vehicle with autonomous driving. Three working groups are created to develop tasks in three well separate areas. Each working group is composed by three students coming from the three original groups, so, after this initial phase, in each group there will be an expert student in each one of the three areas, and this expert student will transmit his knowledge to his teammates during the next phase. These first three tasks are:

- Task 1: Design and construction of the power management system with the requirements of the on board computer. There are several elements connected to this computer like an USB GPS receiver, an USB

Figure 4. Finished prototype with the electronic circuits on a transparent box on its top.

Figure 5. Participating students in Wireless4x4 2009 project

WiFi transceiver and a servo controller (also connected to the servos that handle the vehicle direction and speed). From a battery of 11.1V, the power supply circuit must provide the levels of voltage and current required by all the on board systems. This task also includes the physical construction of the power supply circuit on a Printed Circuit Board (PDB). The specific skills acquired with this task are: analog circuit design, computer-assisted design (OrCAD) of electronic circuits, and PCB construction.

- Task 2: Implementation of a WiFi network for the communication between the control and on board computer, and implementation of the hardware and software platforms. During this task, the students must select a suitable USB WiFi device, analyze the WiFi coverage in the campus and program the required software for the WiFi link establishment between the two computers. Moreover, the students install and configure an embedded computer with a Linux operating system, and mount the basic platform composed by the on board systems. The specific skills acquired with this task are: link budget analysis, WiFi coverage analysis and WiFi network deployment, embedded computers and embedded operating systems configuration.
- Task 3: Implementation of a driving algorithm based on GPS information. The students participating in this task must select a suitable USB GPS receiver, analyze the received GPS information and program the driving algorithm for the autonomous driving of the vehicle along a previously fixed circuit. The specific skills acquired with this task are: GPS signal analysis and processing, basic control theory and software development.

After these three tasks, all the students have to put their knowledge and designs together, in order to carry out the next task.

- Task 4: System integration to complete the autonomous driving of the vehicle. In this task the students put all the pieces together and solves the integration problems that usually arise. The specific acquired skills with this task are: systems integration capabilities.

With the conclusion of this task, the students have reached the project basic goal and the competition between groups begins.

2) Competitive Phase

For this last phase, the students return to their original groups to develop specific system improvements. The aim of this phase is to make the project more attractive to the students, improving their inventiveness and own initiative. Hence, this phase has only one task for the three groups:

- Task 5: Development and implementation of system improvements. The students suggest the system improvements (in the driving algorithm, signal processing or location method) and, after the educators' authorization, implement them in order to win the final race against the others groups. Examples of improvements carried out this year are: improvement of the GPS positioning using a tracking technique by means of a Kalman Filter or improvement of the positioning using a differential GPS.

During all these five tasks, the students also acquire several professional capabilities and skills, represented in Figure 3 as upper outputs of the diagram. Specifically, the main ones are related to: teamwork, long-term scheduling, communication skills, knowledge integration and autonomous learning.

IV. RESULTS

In this section, the results of the three-fold evaluation described in Section III are analyzed.

A. Technical knowledge and professional skills

We now analyze the objective results that have been reached in the project. For the end of the project, the three groups built their fully functional prototypes and competed in the successful race. The winner group implemented a differential GPS system and improved the speed control. However, before the race some last time adjustments were needed in all the vehicles because the designs were not robust enough. Indeed, one of the prototypes did not finish the race because of a bug in the autonomous driving algorithm. After this bug was fixed, the vehicle was eventually able to complete the circuit successfully. A picture of a finished prototype is shown in Figure 4.

Moreover, through the three evaluation points described in Section III, the educators observed the improvements in different knowledge areas and skills like programming, electronic circuit design, embedded system configuration or wireless networks in all the students. Hence, all the students had a positive evaluation due to their participation, initiative and the quality of the prototypes.

B. Students' opinion

A survey of the students' opinion was carried out at the end of the project. The survey was composed by nine closed questions about the knowledge and skills acquired by each student, and two open questions to evaluate the best and worst issues of the project. Table I shows the mean and mode values of the survey answers. Several aspects of these results are noteworthy. All the results show a high satisfaction level about the learning aspects and the general evaluation of the project. Interestingly, all the students confirm that their knowledge and skills related to the different areas of the project have been improved, even in the areas that were not related with their specific task in the cooperative phase.

However, if we break down the results of items two, three and four in Table I, it shows that, for each student, a slightly better result is obtained for the areas involved in his particular task. Although the general evaluation item mean value is very high, it is important to point out that the item related to the acquired autonomous learning capabilities has one of the lowest values.

In the open questions, the students emphasized as the best points the teamwork, the work in a real scenario and the variety of concepts learned. The worst point is the lack of resources and a sometimes-poor organization. Examples of the most outstanding answers of our students are: ``I loved the experience, beyond my wildest expectations, I would recommend it to anyone and my only regret is I cannot do it again."; ``If it hadn't been for my mates, I'm sure I'd have crashed into more things".

C. Educators' opinion

All the educators agree on that the educational value of the project is very high, in terms of both technical knowledge and professional skills. Moreover, the educators also agree with the students in most of the observations given in the previous section, in particular in the organization shortcomings. The main reason for this is the high workload that this project has represented for the involved educators. However, they still are really pleased with the final results of the project.

TABLE I. RESULTS OF THE STUDENTS' OPINION TEST

Item	***Mean***	***Mode***
Through this project my teamwork capability has improved	4.08	4
Through this project my knowledge in analog electronics has improved	3.83	5
Through this project my knowledge in software development has improved	3.42	4
Through this project my knowledge in system integration has improved	4.17	5
Through this project my problem solution autonomy has improved	3.92	4
Through this project my problem solution capacity with time and budgetary constraints has improved	4.08	5
The project is a good integration of knowledge from several areas in Telecommunication Engineering	3.92	5
The project has fulfilled my expectations	3.75	4
Project general evaluation	4.58	5

V. CONCLUSIONS

The Wireles4x4 project is three years old, and at this moment is in the cooperative phase of its fourth year. The results described in Section IV show that the main objectives of the Wireless4x4 project have been fulfilled. Specifically, the knowledge and skills acquired by the students and tested in the three points evaluation are really significant and useful.

Moreover, from the three points evaluation and the student survey, it can be seen that the students acquire an integrated vision of the different technologies involved in the project. In this sense, the main limitation is the difficulty that a student has to acquire those skills that are not related with his specific task in the cooperative phase, as can be observed in the student survey. To overcome this limitation, two improvements are being developed this year: the documentation and the final presentations of the cooperative phase are being improved, and the competitive phase is longer in order to give more time to the students to analyze the whole system.

Moreover, the organization issues of the project have been improved over these three years, but they still are one the weakest aspects of the project, due to the high workload that the project represents for the educators. This year, more professors participated in the organization of the project, and from the beginning, a list of task and a Gantt diagram has been developed and is known by all the participants.

Finally, the summarized opinion of the educators involved in the project is quite encouraging, and the authors are able to predict that this project has still a wide margin for future improvements.

A. Figures and Tables

1) Positioning Figures and Tables: Place figures and tables at the top and bottom of columns. Avoid placing them in the middle of columns. Large figures and tables may span across both columns. Figure captions should be below the figures; table heads should appear above the tables. Insert figures and tables after they are cited in the text. Use the abbreviation “Fig. 1”, even at the beginning of a sentence.

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Cooperative assessment in the hands on skills of computer networks subjects

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Abstract—**The cooperative assessment system promotes teamwork, increases the mental practice and develops the social skills that are so necessary in the working life. In this paper we present the experiences and methodologies undertaken to assess the subjects "Local Area Networks" and "Networks Integration" of the Degree in Technical Engineering in Telecommunications of the Higher Polytechnic School of Gandia of the Polytechnic University of Valencia, Spain. This courses attempt to stimulate the students' motivation and teamwork through various activities and to provide the appropriate training to safely resolve situations that may be happen in real life. This article shows the opinions of the students, their feedback and their marks. All these data will be used to improve the teaching methodology for the next year. Finally, we can say that the main aim of the courses has been achieved, because the survey results, the opinions of these students, and their marks have been very satisfactory.**

Keywords- Cooperative assessment, Collaborative groups, Work in groups, Problem-Based Learning.

I. INTRODUCTION

The assessment of the student's training, as an individual or as a part of a group, is a process that has to be continuously done along the course. Moreover, the end of the teaching period carries a closure and any closure involves some results review. But, what and how should we evaluate it? These questions are very difficult to answer when a complete assessment of the skills of the students is wanted.

The evaluation can be conceptualized from different points of view. It is important to know the difference between the formative evaluation and the summative evaluation. In the first type of evaluation, the information is used to guide and to improve the learning and training processes. In the summative assessment, the information is used to determine the student's final mark, which gives the learning level of the student, and the marks that are added to the final part.

Sometimes the assessment process may be understood as a set of useful tools in order to improve the quality of the teaching-learning process. The relationship between the quality of teaching and the evaluation is narrow and, generally, it is difficult to mention one of them and forget the other concept.

According to [1], the training assessment is not only to measure, qualify or to grade the student answers. It is neither to sort nor to examine the students. Nevertheless, the assessment is usually related to many activities like qualify, measure, edit, sort, certify, review or pass the tests, etc. Both concepts share a semantic field, but it should not be any confusion between them. Both concepts are differentiated by the resources, its use and its serving purposes. The training assessment allows improving the practice. The non-training assessment, where you cannot learn from the assessment, should be excluded in the basic levels of education. The evaluation process should be a resource for training and a learning opportunity.

In [2], Rodriguez et al. recommend that a practical assessment has to be objective, comprehensive, brief and very practical. In [3], we can see that practical assessments carry some difficulties. There are some problems that often appear when a hands on skills session is given in the laboratory. These are me main ones:

- The lack of attention to the lecturer explanations. When the students have a computer connected almost always to Internet, while they are in the laboratory, they usually read the mail, see some Social Network like Facebook, Friendster or Hi, finish the hands on skills of previous sessions, etc.
- The lack of customized attention. The overcrowding of the laboratory classes force large groups of students, thus the individual attention is very limited. Not so much time can be devoted for each student.
- It is difficult to detect possible problems of understanding before the final correction of the practice is done. Questions like "do you understand?", "is there any question?" or "is there any doubt?" usually do not provide any feedback from the students.
- The lack of material resources and equipment is a problem that must be considered. Usually the laboratory equipment has to be shared by several students.
- Practical sessions imply a greater dedication by the lecturer in the stage of activities preparation and in their correction.

In contrast to the issues previously mentioned, and due to the technological advances, the learning process is being centered on the student figure (learning) and not so much on the lecturer figure (teaching) [4]. For this reason, problem-based learning (PBL) methods are used. According to [5], PBL can be defined as the learning method that ensues to work towards the knowledge of the problem resolutions. The PBL method is based on the following rules [6]:

- The students have to assume the responsibility of their own learning.
- The problems should be intentionally unstructured and it should allow free interpretations.
- The learning should be directed towards a wide range of possibilities, not towards a single knowledge specialization.
- The concepts learned in the study stages and in the independent learning must be applied to the proposed problem.
- On one hand, it is necessary a final synthesis of the learned information and, on the other hand, it is necessary to define what concepts have been learned, and which ones would be necessary to be reinforced before initiating the evaluation process.
- The evaluation and auto-evaluation must be done when a problem is finished and at the moment of ending the chapter.
- The individual student evaluation must be realized always bearing in mind the proposed aims.
- The topics and the activities should be focused always to real-life examples and these activities should contribute the values of the social and professional areas.
- The cooperative teamwork, the collaborative learning and the personal autonomy, have to be taken as the essential keys of the work.
- The PBL should constitute the pedagogic base of the curriculum and not only a part of the education.

The students assume major freedom of action and responsibility in PBL. Moreover, the lecturer takes a new role, that is, to direct the students through the learning process. The success of the PBL highly depends on the preparation, the background and the training of the lecturer. In general, PBL must allow developing the professional qualities that are demanded in the current world: constant learning, autonomy, teamwork, critical spirit, communication capacity and planning.

One of the main problems in the cooperative methodology assessment is to evaluate the individual marks of the student's knowledge about the content of the subject. To evaluate the cooperative competences learned during their cooperative tasks is also difficult. The lecturers must also control shirk students and the students' cooperation [7] [8].

The rest of paper is structured as follows. Section 2 describes some works and gives some related experiences about the assessment process of the student's training. Section 3 explains our didactic methodology and cooperative assessment. The teaching process and a survey performed by the students to evaluate the method are explained in Section 4. Section 5 shows the students' opinion. The student's marks are presented in section 6. Finally, Section 7 gives the conclusions.

II. Related Work

A special interest in the use of collaborative teaching methodologies in the teaching-learning process of student [9][10] and lecturers [11] is in the university training. This happens mainly due to the benefits provided by these methodologies to the students, in addition to the skills that they develop.

One of the first questions we must be asked before starting any collaborative methodology is what issues must the teachers bear in mind before designing a cooperative learning program?. It was discussed by E. G. Cohen et al. in [12]. They presented different pedagogical methods performed in the Toronto University that are related with the cooperative learning. There are other pedagogical methods for Classroom Practices that are based on cooperative learning such as the ones presented in [13]. These ones have inspired us to perform our methodology.

With the renewal of the study plans and the migration towards the Bologna Process, many schools and centers have included modifications in some of their subjects and have gathered the results at the end of the course to compare it with the previous experiences. An example is given by the EUETIB (Escuela Universitaria de Ingeniería Técnica Industrial de Barcelona) [14]. It has reviewed and improved the objectives and programs of different subjects applying the techniques of CL (Cooperative Learning). A. Perez et al. show in their paper the academic achievements in the first year of implementation of these subjects. The results were satisfactory and the cooperative learning experiences have proved to be a motivational tool to improve the academic outcomes compared to their performance in individual tests. In addition students appreciated the functioning of these subjects.

Another related work about practice training is shown in [3]. It is presented by M. Riesco et al. The authors analyze the consequences of implementing the system of electronic answer (Electronic Response Systems), also named Classroom Communication Systems. This system has been used from the ends of the 50s as a reinforcement to the teaching of different matters at different levels. These systems attempt to provide a technical element to each student and allow them to interact with the lecturer. The authors say that despite of its diffusion throughout the world, there is no record of an employment in Spanish universities.

Another example can be found in [15], where M. Marques et al. explain the experiments carried out with some students. Their main goal was to improve the students' motivation through different activities. These experiments are applied in a subject called "Design and management of databases". They change the training methodology and even the qualifications weighting, giving, for example, major weight to the practical activities than to the theoretical ones.

Since several years ago, several lecturers of the Higher Polytechnic School of Gandia, of the Polytechnic University of Valencia, are working with the introduction of different types of training methodologies. These skills are applied to different subjects of the Degree in Technical Engineering in Telecommunications [16]. Collaborative Learning is the method that is used in the subjects "Local Area Networks" and "Networks Integration". Both subjects are placed in the third course (last course of the degree), thus it is the best place where collaborative learning could be implemented because when the students finish they would collaborate with other partners in the enterprise.

III. COOPERATIVE EVALUATION

First of all we must define the meaning of cooperative learning. In general, it is a pedagogic skill where the students work together towards the attainment of a common target and every individual will reach the aforementioned target if – and only if – the rest of members of the cooperative group also reach it [17].

In order to evaluate the teaching-learning process, the following methodology of cooperative assessment has been designed. The activities that will be explained are focused on learning methods based on problems (PBL). These activities serve as a preparation for the student in order to meet several scenarios that emulate real world problems. When this stage is finished, several problems, similar the previous ones, will be followed as evaluation criteria in order to value the attainment of the proposed targets. This assessment system has been performed for several years in the third course in Degree in Technical Engineering in Telecommunications of the Higher Polytechnic School of Gandia, Valencia, Spain. The overall length is eight months divided into two parts. The first four-month period prepares the students to overcome problems in the field of local area networks (the subject is called "Local Area Networks"). In the second four-month period the complexity is higher because the students work with wide area networks and they should be able to integrate these networks (the subject is called "Networks Integration").

One of the best teaching methodologies to perform this procedure is through practical training. The lecturer accommodates the theoretical contents previously learned in the classroom to the practical training. In each practice there is a theoretical introduction to the practice that has to be done by the students. The students use a guide to follow the practice. The guide introduces the student to the different activities that have to be performed. Along the guide, there are various items that the students must fill up as process control in order to encourage their self-assessment and their learning. We must highlight the cooperative aspect of the practical activity, because even though the students have a guide that helps them to carry out the practice, they will not be able to finish it until the partners don't finish their part correctly. After it, they will be able to check the proper running of their configuration.

During the first four-month period the general concepts and objectives to be evaluated are the following ones:

- The knowledge of the basic elements of a local area network and the network configuration of Windows XP Operative System.
- Windows XP network commands and network troubleshooting.
- Setting up a Windows 2003 Server.
- Wire Cabling, crimping and test.
- Configuration of Linux Operative System.
- Network Configuration of Linux Operating System.
- Installing a WLAN network.
- Allied Telesyn switches configuration.
- Cisco Catalyst switches configuration.
- Routing between VLANs using Allied Telesyn devices.

Along the second four-month period the general concepts and objectives to be assessed are:

- Routing between VLANs using Cisco Systems switches and routers.
- NAT and PAT configuration in Cisco Systems Routers.
- NAT and PAT configuration in Allied Telesyn routers.
- Cisco router Command Line Interface.
- RIP routing protocol configuration with Cisco Systems routers.
- RIP routing protocol configuration with Allied Telesyn routers.
- OSPF routing protocol configuration with Cisco System routers.
- OSPF routing protocol configuration with Allied Telesyn routers.
- LANs interconnection using 3COM ISDN routers.
- LANs interconnection using HDLC and PPP in Cisco Systems Serial interfaces.
- Installation and configuration of a Frame Relay network using Cisco Systems routers.
- SNMP management.

We can observe that the practices touch a wide range of topics related with local area networks (in the first four-month period) and integration systems (in the second four-month period). They have been elected in order to cover all knowledge needed by a student to build a local area network of an enterprise in the first one and, in the second one, to interconnect data networks from different locations (headquarters with its branches, central office with remote or mobile workers, etc.)

The evaluation criterion is established according to the following objective: The student will pass the subject only if the lecturer will recommend that student to an enterprise when it looks for someone to carry out the same issues in the real world.

The main goal of the assessment system is to motivate student's continuous learning, promote the team working and to develop the student's communication and scheduling abilities. The evaluation is mainly divided into two stages in each four-month period.

In one stage the student applies the acquired theoretical knowledge to practice sessions. In order to do so, a guide with the steps to follow for each practice session is developed. Initially, the practice is performed individually, but in a certain stages, it can't be completed unless another student has finished his task, so it is needed collaboration. That is, the student needs a partner to carry out his/her task because if they perform their part correctly, all the system will function properly. On the other hand, if a student has any sort of doubt he/she may exchange his/her opinion with other students. This learning process will always be supervised by the lecturer. The supervision will be focused on the group dynamics when it is required or whenever he considers necessary for the optimum development of the activity. In order to pass to the next stage, the student has to complete the 80% of the practical activities at least.

In the assessment stage, a final practice assessment using students' collaboration is made. In order to complete the this stage, the student will have at his/her disposal all the devices and tools he/she may need (wire, crimping tools, routers, switches, Personal computers,…) in order to carry out the assessment. These devices and tools are the ones that have been used in the practical activities performed in the first stage. A laboratory is also available during several days for the students that want to repeat the practices or to practice with new situations. During the week before the practical assessment, the lecturer will answer the questions made by the students and will propose similar topologies in order to improve their practical knowledge. The participation and assistance during this week is optional.

In the final practice assessment a real situation is simulated. It is presented to the students 24 hours before the exam date. It lets the students to prepare it and to plan an appropriate organization to face the problem raised. During those 24 hours the students are able to consult the practices they have done before and go to the laboratory in order to test any configuration. They can also exchange information with other students in order to find the correct configuration.

When the final practice assessment takes place; the lecturer randomly assigns students to several groups (although it can be done letting them to organize the groups). The students must collaborate with their partners in order to perform their task. The tasks will also be assigned randomly, but the lecturer could introduce some new problems, even discrimination, because every task shows different level of difficulties.

The information given to the student is the following one:

- The lecturer is only an observer of the work. He/she will not give solutions or give any clues about the proper solution.
- The individual task has to be fully configured in 2 hours. There is also half an hour for helping other students.
- The assessment is evaluated as follows:
  1. Group task:
     - Cooperating and collaborating between the members of the group.
     - Total time needed to configure the network. If it has been done in less time, they will be awarded.
  2. Individual task.
     - The correct configuration of the individual task.
     - Level of difficulty of the task assigned (notice that it is more important to correctly terminate an easy task rather than not finish a harder one).
- Recommendations to do the exam:
  1. To make democratically a work plan among the group members to perform the activity.
  2. Assign the roles of the group members. But, with no student names assigned to them.
  3. Execute harder tasks with the help of other students (more solutions in case of not having the right result).
  4. Do not install or uninstall drivers unless it is necessary. These should be fully working.
  5. It is recommended to set hardware to default settings (switches, routers, access points,…)
  6. Support each other in order to solve the tasks and promote a good environment between the members of the group.
  7. Always be in calm in case of having any problem during the activity.
  8. Have an alternative plan in case undesired results.
- Test goals:
  1. The network should be finished in a given time.
  2. Obtain the proper results when the lecturer tests the network.

- Gather the network assessment data, solve the problems found during the assessment and answer the questions.

To conclude the description of this assessment system, we now shall talk about which is the criteria used to put the students' marks. The group mark will depend on the global results obtained by the group for the hands on skills assessment. The individual mark is obtained according to grade of correctness and the collaboration or the information exchange between the students during the exam. The final mark is obtained from both, the individual and the group mark. The lecturer assigns the mark based on his observation and supervision when the practice assessment is done. The lecturer checks that each task is performed correctly and that the dependences between tasks are well done. These dependences help the lecturer to know the collaboration between the students in both individual and between the members of the group.

Generally, if the student's task is not well done, his/her mark is bad. Moreover the group's mark will be affected. It happens because the lecturer considers that the group has not collaborated with this student enough to carry out that task. Thus, if there is not any collaboration between the students, it will affect negatively the final mark of the group.

IV. Students' Opinion

Once the final practice assessment and the test performed by the lecturer are finished, the student receives a questionnaire in order to know their opinion. The questions are shown in Table I. The questions give their opinions about the course, theoretical contents, if they enjoyed the practice classes and the improvement areas for a further course. The questionnaire was fully anonymous.

TABLE I. Questionnaire

Nº	Questions	Valuation			
		None	*Little*	*Quite*	*Very Much*
1	Was the theoretical knowledge enough for the practice classes?				
2	Was the material adequate?				
3	Did the facilities made easier the teamwork?				
4	Was the length of the practice classes adequate?				
5	Was the number of practice classes enough?				
6	Was the final practice assessment difficult compared to the practice classes?				
7	Does the collaborative work system make easier the learning process?				
8	Is the system used to assign marks adequate?				

A part of this questionnaire, the Polytechnic University of Valencia makes its own regular questionnaire for all subjects that are taught in every school and faculty of the university. This questionnaire is presented to the students few weeks before the course ends. They are also fully anonymous, to protect students towards any lecturer's reprisal. They evaluate aspects like didactic material, slides and books, the resource usage, quality of the master class, etc. The results are presented to the lecturer once the course has finished, thus he can self evaluate and improve his training method. But university questionnaire is different of the one presented by the lecturer at the end of the final assessment, which is more focused on the teaching method.

As a result of the questionnaire made along this work, a serial of graphs were obtained from the information gathered from all groups. The results are shown in the next section.

V. Results and Discussion

The following graphs show the results of the questions. We show the answers obtained for each question. The average marks are rated over 100% of all answers obtained from the students.

Fig. 1 shows if the theoretical knowledge is enough for having the hands on skills. The 62% of them totally agree with this statement, around 38% believes that the theoretical knowledge should be wider. Assuming that students can extend their theoretical knowledge on their own, and with the huge amount of satisfied students, we conclude that theoretical knowledge and hands on skills are balanced.

The results for the second question are shown in Fig. 2. Half of the students have total grade of satisfaction with the used material, meanwhile the other half quite agree. This happens because the Higher Polytechnic School of Gandia has very well equipped laboratories in both quality and quantity. It makes the students to work very comfortable during their practical classes.

In fig. 3, the results show that almost 50% totally agree that the facilities make easier the teamwork. A 38% thinks it should be improved some how. Approximately 12% of them disagree this statement. We think that these results have not been higher because in the actual educational system the students do not work in groups. At the beginning is harder for the students and they do not notice its advantages.

Fig.4 shows that half of the group disagrees with the hands on skills length. This is mainly because if any problem appears, the time needed to finish practice increases significantly. It is important to notice that 35.50% quite agree and 13% totally agree. In further research, we will take into account if the student has previous experience. These results may give some new criteria for group formation.

Fig.5 shows that 63% of the students agree with the number of hands on skills made toward 37% that disagree. We should remember that this is a hands-on-skills-based learning method and the number of practices is quite high. The total amount of work is high, thus some students get carried better than others (which is reflected in their results).

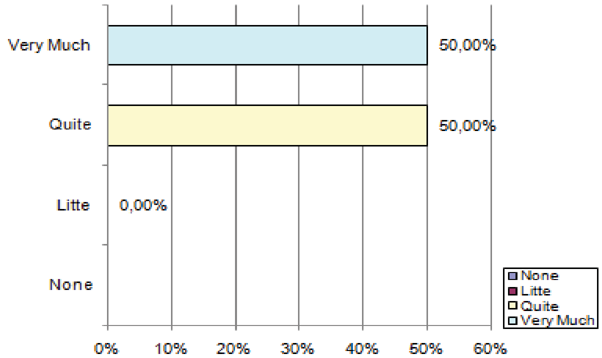

Figure 1. Results Question 1

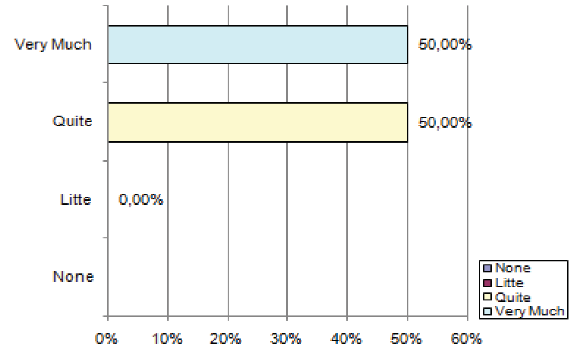

Figure 2. Results Question 2

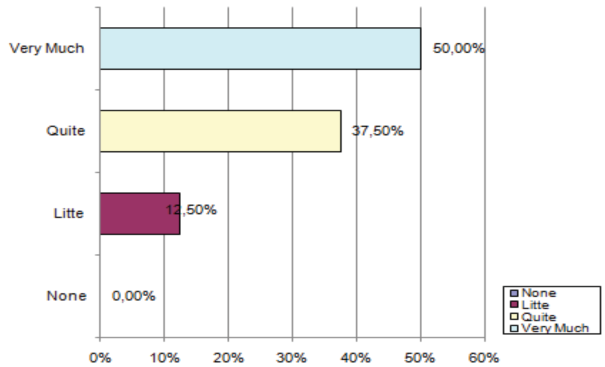

Figure 3. Results Question 3

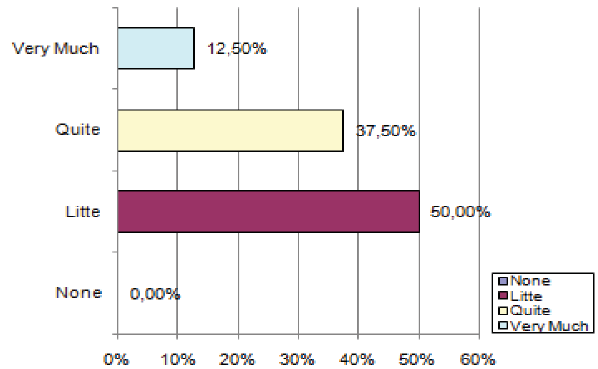

Figure 4. Results Question 4

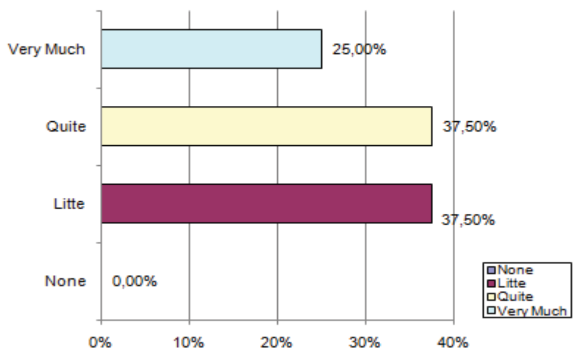

Figure 5. Results Question 5

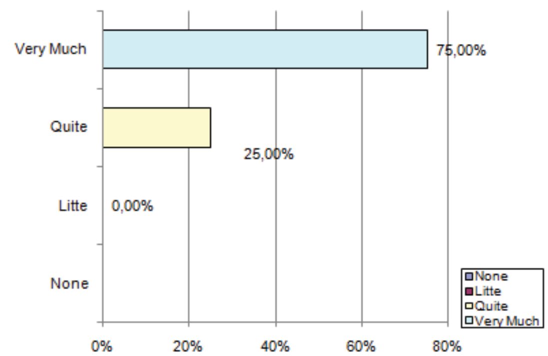

Figure 6. Results Question 6

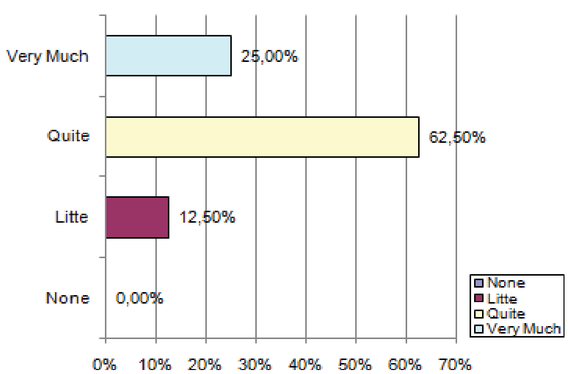

Figure 7. Results Question 7

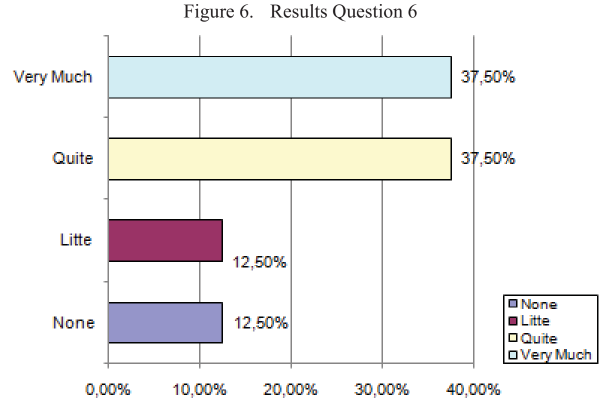

Figure 8. Results Question 8

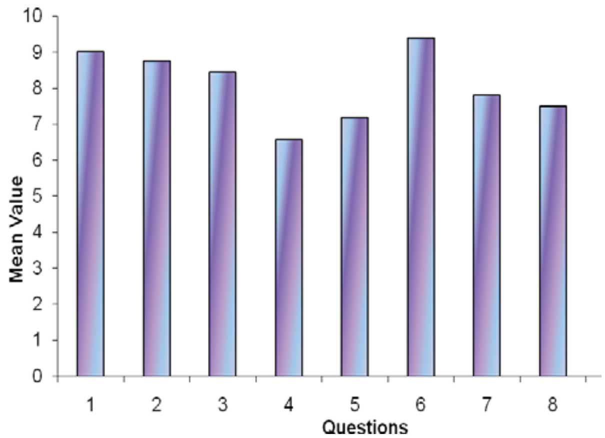

Figure 9. Mean Value about over 10 about the survey result.

When we asked the level of difficulty of the hands on skills, we see that students feel absolutely satisfied with them. Their answer is shown in fig. 6. Thus, we have achieved the goal of having the same level of difficulty in the hands on skills than in the final assessment practice.

In the question of the balance between degree of learning and team working, we obtained the results shown in Fig. 7. 87% of them agree or totally agree and very few disagree (13%). This question is quite related with question 3. The students that don't see the benefits of the teamwork will not appreciate its influence in the learning process in a collaborative work. Some students think that the collaborative work is an extra load added to the existing work instead of an exchange of experiences and knowledge. It mainly happens in those students which knowledge overcomes the others.

In the assessment system, there are different opinions. Fig.8 shows that 74% agree and 26% disagree. Notice that their mark is obtained from both, the individual and the group mark. On one side, this system let the students, which couldn't reach high marks individually, take advantage of the group marks. But, on the other side, the individual marks let us to reward the effort of the distinguished students.

In fig. 9, we see that, in a general way, students do appreciate the method used in these subjects. All questions have an average value higher than 8. Assuming that with these questions, to reach a vast number of variables is wanted, which are involved in the training-learning process, we understand that the global average of these questions are significant indicators of the degree of satisfaction and perception seen by the student.

VI. STUDENTS' RESULTS

In this section we show the results and the global average marks obtained by the students that have undergone this training method. We highlight that the whole number of students that carried out this assessment was low because the classes are formed by reduced groups. In Local Area Networks subject there were 8 students in 2007-08 course and 14 students in 2008-09 course. In the Networks Integration subject there were 22 students in 2007-08 course and 11 students in 2008-09 course. As it has been aforementioned in this paper, we gathered data from the students of both subjects. Therefore this section shows the results obtained from both subjects during the academic years 2007-08 and 2008-09.

Table II shows the subject "Local Area Networks" during the course 07/08. There were 8 students. 6 of them made the final assessment. The average marks obtained by the students that pass the exam were 8.1 points. Figure 10 shows that the 75% of the students passed the exam, but the 12.5% did not pass it.

Figure 11 shows the global marks taken by the students of "Local Area Networks" subject during the course 2007-08. Most of them have a mark higher than 7. We can see that the students obtain high marks.

In the next year, the same subject was attended by 14 students and in this case, 11 of them made the exam. The global average mark obtained by the students that pass the assessment in this course was 7.85 points. This information can be seen in Table III.

Fig.12 shows that approximately 7% of students failed the exam, compared to 71.43% that it passed it. It demonstrates that the number of students that pass the subject is quite high.

Fig.13 shows the average marks of the students during the course 2008-09. We can see that almost all obtained marks between 6 and 10 (3 students obtained a mark between 6 and 7 and between 9 and 10, and 2 students obtained a mark between 7 and 8, and between 8 and 9).

The subject "Networks Integration" is taught in the second four-month period. During the course 2007-08, 22 students were enrolled in this subject, but 2 of them did not take the assessment. The global mean mark obtained by the students that pass the exam was 7.29 points. These values are shown in table IV.

Fig. 14 shows that only 9% of the students decided not do the final assessment. 18.18% of the students failed, but, on the other hand, the 70.72% passed it.

The average marks of the students that passed the assessment of the subject "Networks Integration", during 2007-08, remained close to 8. We can see in Fig.15 that most of the students had a mark between 7 and 8.

Network integration subject had 11 students during the year 2008-09. In this case 7 students made the exam. The average mark obtained by the students that passed the assessment of this course was 8.87 points. This information can be seen in Table V.

Fig.16 shows the percentage of the students that passed, failed and didn't do the assessment of the "Networks Integration" subject during the year 2008-09.

Finally, Fig.17 shows the students marks of the subject network integration in the year 2008-09. The mean value of the marks is between 7 and 8.

TABLE II. LOCAL AREA NETWORKS IN 07/08

Course 07/08	Local Area Networks		
	Total Students	***Students who have made the exam***	***Global Mean Mark***
	8	6	8.1

TABLE III. LOCAL AREA NETWORKS IN 08/09

Course 08/09	Local Area Networks		
	Total Students	***Students who have made the exam***	***Global Mean Mark***
	14	11	7.85

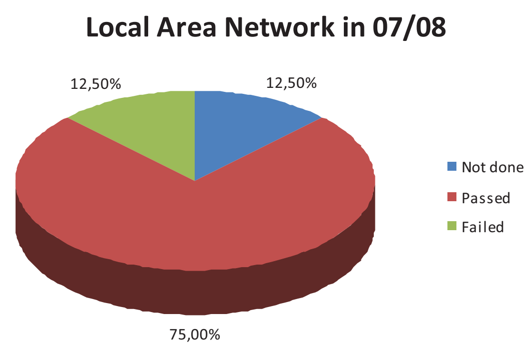

Figure 10. Percentage of students in Local Area Networks in 07/08

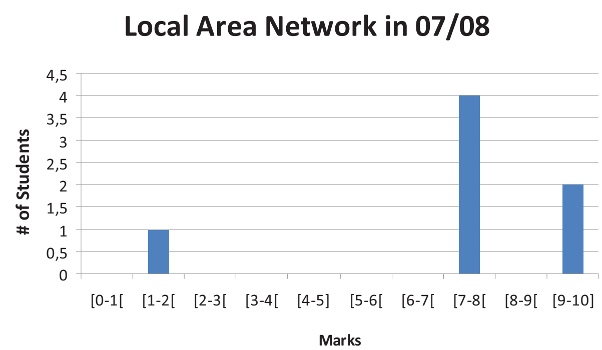

Figure 11. Global Marks in 07/08

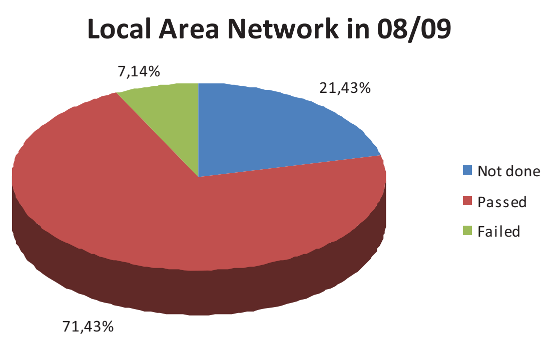

Figure 12. Percentage of students in Local Area Networks in 08/09

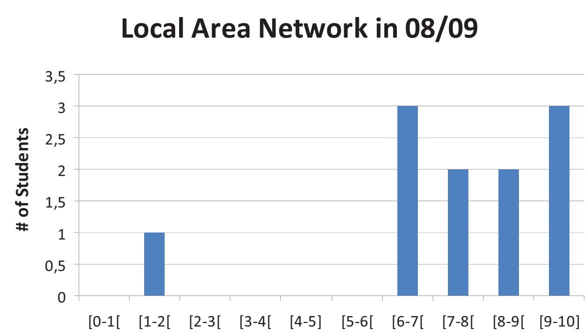

Figure 13. Global Marks in 08/09

TABLE IV. NETWORK INTEGRATION IN 07/08

Course 07/08	Network Integration		
	Total Students	***Students who have made the exam***	***Global Mean Mark***
	22	20	7,29

TABLE V. NETWORK INTEGRATION IN 08/09

Course 08/09	Network Integration		
	Total Students	***Students who have made the exam***	***Global Mean Mark***
	11	7	8,87

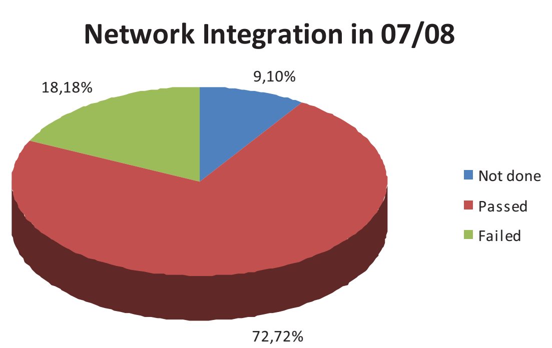

Figure 14. Percentage of students in Network Integration in 07/08

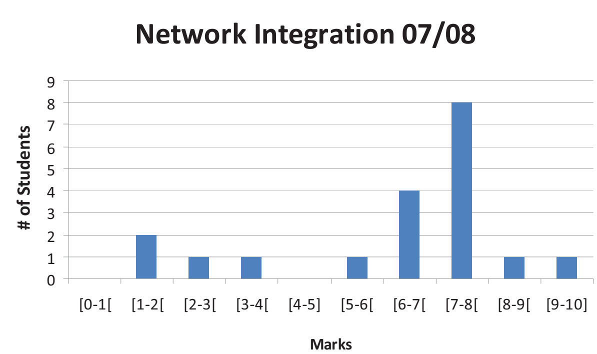

Figure 15. Global Marks in 08/09

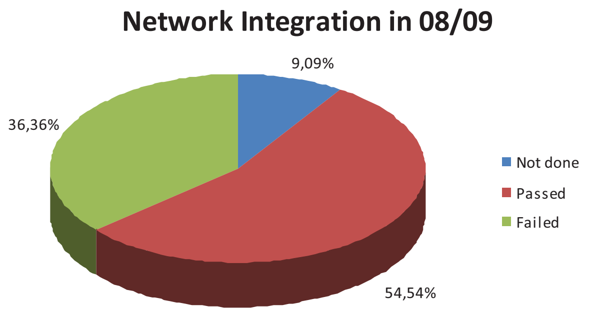

Figure 16. Percentage of students in Network Integration in 08/09

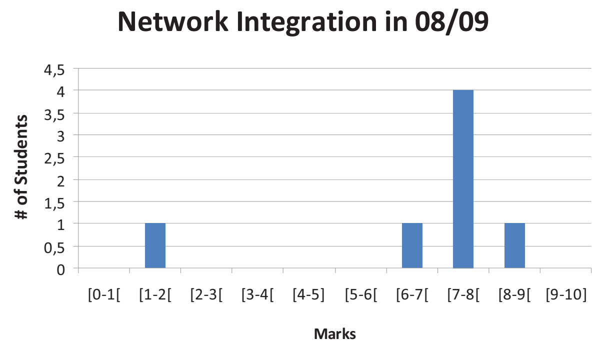

Figure 17. Global Marks in 08/09

VII. Conclusions

In this article a hands on skills collaborative assessment method has been presented. It is carried out in the subjects "Local Area Network" and "Networks Integration" of the Degree in Technical Engineering in Telecommunications of the Higher Polytechnic School of Gandia of the Polytechnic University of Valencia, Spain. This study shows that the method had a positive acceptance by the students. Compared to other subjects, students have higher final marks and there are more students that pass this subject than other subjects.

This study also gives us enough reasons to prove that the didactic method used in these two subjects is effective. The training-learning process has a positive feedback for the lecturers because the students are more motivated. The active learning style makes easier to acquire knowledge, which is the main goal for the lecturers and students. The hands on skills in the laboratory and the collaborative assessment push the students to learn from real situations and problems, and from the experience.

The main drawbacks or difficulties observed from the point of view of the teacher have been that the lecturer has to be a high expertise in the topics of the subject. He/she has to be able to solve any issue quickly and, always, giving an appropriate explanation. Moreover, he/she has to be updated about the new technologies in existence in the market. It is also recommendable to be in the enterprise for several years in order to learn from this environment its difficulties and problems. Then, it will be easy to transmit these skills to the students. Finally, we have to say that the first year is the one that more time is needed to implement it. The lecturer uses a lot of time designing the method and solving the holes derived from implementing a new idea. The second year is used to fix any issue observed and to systemize some parts in order to make an easy and quick implementation method.

We suppose that there is high number of students which are interested on these subjects, motivated and, finally, have passed the assessment because of the type of methodology used. Both subjects are practical and both have hands on skills assessment, which make the students to be initially interested in enrolling in it. At the end of the two subjects, students are positively surprised, because the practices that they carried out can serve them to enter a workplace and perform their duties without problems.

Now, we are working in several issues in order to improve the methodology. On one hand, we shall exhaustively analyze the way to form the assessment groups. It may be formed using any type of criteria (according to their knowledge, temper, special interests, etc.). On the other hand, we shall study the number of members in each group and their impact in the final mark.

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A Tool to Reveal the Student's Work Activity Along an Academic Period

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Abstract— **This paper presents a web application designed to allow better workload distribution during a semester. The tool was designed to face the new goals that are required for teachers that work within new methods that are fostered by the Bologna Treaty implementation. The tool can help course administrators to improve the effect of some extra-initiatives (talks, workshops, tours, short courses, amongst others), without compromising the performance of students on their work scheduled for the course activities. The paper presents and discusses the motivation and the developed tool.**

Keywords-Internet; education; workload; pedagogy; interaction

I. INTRODUCTION

Nowadays high education institutions, all over Europe, are getting the first results from the implementation of the Bologna Treaty guidelines. According to [1] this treaty's main goal is "… to create the European higher education area by making academic degree standards and quality assurance standards more comparable and compatible throughout Europe, in particular under the Lisbon Recognition Convention…"

After the treaty implementation, in several Universities, Polytechnics or High Schools, the results begin to emerge and are in some cases reasonable but on the other hand there are some unsatisfactory results. These results depend not only on the institutions where the treaty was implemented but also from the actor's (teachers, students, etc.) point of view. According to [2], one of the consequences of the Bologna treaty is that "Teacher-centered knowledge-based teaching, resulting from memorization, turns into more democratic and balanced model where the student and teacher are closer and where personal contact is more prolonged and with more benefit for both. In this new model the student is responsible at a different level his/her work being more independent, autonomous and creative.". This means that the student's learning process is more based on the work and research they do, in an active way, than on the passive listening to what teachers say. A consequence is that teachers propose several works that must be done by students in the scope of the classes/subjects that they are registered on. This can lead to an excessive workload during certain phases of the semester or academic year.

It isn't our purpose to analyze the Bologna treaty implementation in this article. Our goal is to present an application that was designed to help the supervision of students' workload and to help teachers to have an idea about the amount of work of their students, having also in consideration the other teachers work proposals to those same students. This necessity was detected throughout the students' feedback that complained about the excessive workload required by the teachers during the semester. As consequence of this excessive workload we have notice an increasing class absence of students in the last weeks of the semesters because the deadlines to finish and deliver their works are generally in this period of time. If students have subjects from previous academic years, due to failure in past year(s), this scenario becomes even worst. To try to smooth the student's workload and give a different perspective to the involved teachers, a web application was designed and it is the main contribution of this paper.

II. THE TARGET SCENARIO

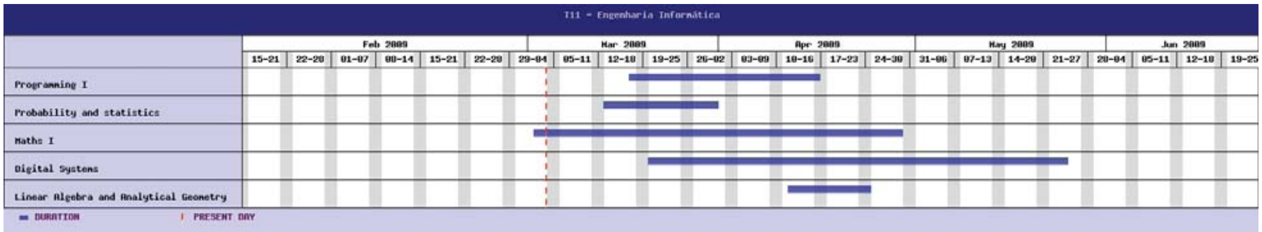

Figure 1. Gantt chart (Student's view)

In our department, Computer Engineering department of a Technological Engineering School in Portugal, before the adjustments to the Bologna Treaty guidelines, we had several courses with a ten semester's curriculum to achieve the degree of Licentiate. The five years required to graduate was at that time accepted by the national Engineers Professional Organization [3] (OE) as the minimum requisite to be its member; in other words the time needed to be allowed to develop a professional engineering activity. On the other hand, students could finish the course in the end of the 6^{th} semester and obtain the Bachelor degree. They could then begin to work, but with only these three years formation they could not apply to bean OE member. Nevertheless they could be recognized professionals by another institution, the Technical Engineers organization [4]. After taking their degree, students can continue their studies, masters or PhD, in other education systems, mainly universities in the specific case of the PhD.

Nowadays, in the Bologna era, courses passed from 5 years to 3 or 4 years duration, and the bachelor degree has disappeared. Post-Graduations and Masters became a 1 or 2 years complement and the PhDs became a 3 years program.

In this new scenario, after the course adaptation to the Bologna Treaty format, and based on our experience dealing with the students of our degrees (courses with 3 years duration), we have notice that students, complain about the excessive workload in the last half of the Semester. On the other side teachers don't have any information concerning the workload requirements by all the other subjects on a certain academic semester of a particular course. This "blind" reality, even to those institutions that possess e-learning platforms, fosters to situations that leads to an excessive workload. This can affect the students' performance/success. To give visibility to the work demanded by the several subjects of a given course, and to provide a clear overview of the work required from students, we propose a web tool that will be explained in the next section of the article. This beta version will be available in the next academic year and we expect to improve the work planning process from the point of view of students and teachers.

To resume, as previously referred, teachers suggest work proposals without knowing the others subjects' schedules/workload, and no previous knowledge about other activities (exams, workshops, study trips, etc). This led to students complains about an excessive workload in specific periods of the semester and inefficient work distribution during the semester. This motivates the design of an application to make visible the demanded student's work for all actors (teachers, students and course coordinators), to make easy to share information about the proposed works deadlines, to allow a global view about the course activity deadlines, and to allow all actors to contribute and interact with it. The tool presented in this paper was designed to allow these requirements. It is a web application that is described in the next section of the paper. This tool was already described on [5], and in this paper we add some new features that were adjusted/included after feedback from users that used a preliminary release of the tool.

III. The Tool

To implement the proposed tool, a web application was developed to enable all the management and view of the expected workload for a class/subject/course. The actors are the students (targets of the work proposals) and teachers (acting as general chair and the others acting as work proponents). The system was developed as a PHP [6] application with a MySQL [7] database engine. The back-office and front-office parts allow the management of all the interactions between the actors (registration and user hierarchy) and also the user-system interface respectively. In our opinion the interesting contribution of this paper is not the software application – because it is common to others already available - but the target application in terms of pedagogical issues and goals.

In the case of the proposed tool, some of the actions allowed for each actor are:

Administrator: validate teacher's registration; define the subjects for each course; consult any information in the system;

Students: See the time schedule and time duration of the proposed works and estimate the expected workload for a

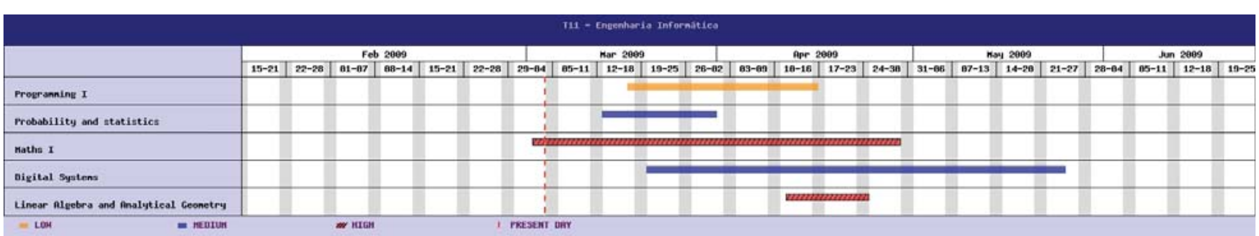

Figure 2. Gantt chart (Teacher's view)

semester/course.

Teachers: Insert/change/delete a work proposal (time duration and difficulty). See all the already proposed works for certain class; visualize the global workload of their students.

Fig. 1 shows a screenshot of the application from the students and the visitors' point of view. Here we can find information about each subject of the semester. In our case, during a semester for a certain academic year (3 years to obtain licentiate degree), there are a large number of classes (usually a class has approximately 25 students enrolled in it). In Fig. 1 is presented the case of the class possessing the ID T11 (1st year, 1st class) for the "Computer Engineering" (in English) / Engenharia Informática (in Portuguese)" course. Using this view, the visitor can easily observe the Gantt chart of scheduled works. Teachers also have a similar view of the already proposed works, by other colleagues, thus having an idea about the required effort, because the work difficulty estimated by the other proponent teachers can be observed and distinguished by different colors (Orange - Low difficulty, blue - medium difficulty, Red - high difficulty), Fig. 2. By consulting this view, teachers can analyze the scenario before launching their work proposals/plans.

Students are not allowed to see the color code, because after feedback from colleagues, we conclude that this is not intended to limit the work's difficulty or to be used by students as excuses. The goal is to alert and help to improve their schedule and not to limit the teacher's goals for their subjects. The teacher will always have the last word, but knowing the global scenario that is being impose to his students, in a non-blind scenario. Fig.3 presents the GUI for students to choose classes. After that, they can consult the Gantt chart for the selected class, interface will be then similar to Fig. 1.

Teachers are validated by the systems' administrator. They are allocated to subjects of certain course. A teacher can only edit the time schedule for his subjects. But when editing the workload for his subject he/she views the scenario expected for the student's semester, in other words, all the works already scheduled for a particular academic year and semester. The teacher's view using the GUI to insert/edit a work for his subject is showed in Fig. 4.

As we can observe in Fig. 4, the teacher in the left can see and choose to edit the settings for the subjects allocated to him by the supervisor. In this example the teacher Jose Metrolho has two subjects for this semester which are: "Software Development" and "Computer Architecture". For each of these subjects it will appear in the right area the global scenario according the course curricula. For example, in case of "Computer Architecture" it will appear in the right area the already scheduled works for other subjects of the same course and semester. This means that before editing/inserting a work proposal, the teacher has a perception of the already demanded effort to those students. This is the goal of the application.

To insert a new work a form must be filled, as can be observed in the right down area of Fig. 4 (Title, beginning and deliver date, difficulty level, if it is a written exam (in this case will be set only the start date) and optional about that work details that will be available for all visitors).

Figure 3. Graphical User Interfacefor students to choose the their classes (minimum of one) within certain course. Each class has several subjects. Each subject as a Time Gantt chart similar to the one showed in Fig.1.

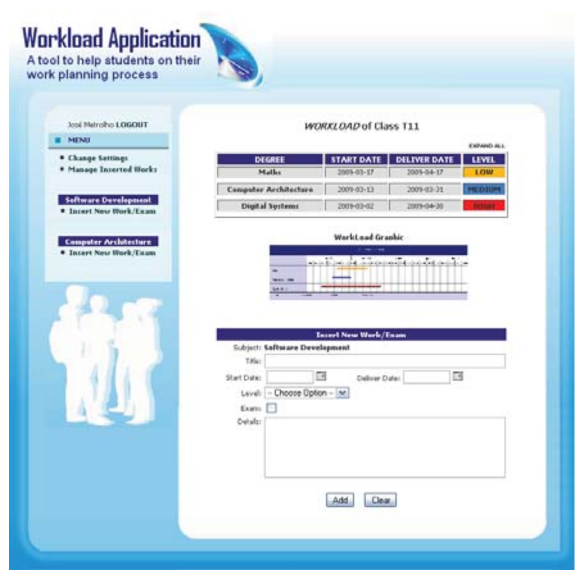

Figure 4. Graphical User Interface to propose a work by a teacher

The administrator is responsible to define the set of subjects for a certain course, insert all the courses and corresponding curricular plans. Fig. 5 shows a screenshot from the subject vs. course correspondence. A subject can be common to one or more courses. He is the one also that inserts the teacher's name and the corresponding email address, Fig. 6. The password is automatically generated for each registered teacher and the system sends it by email. The teacher-subject correspondence is also set by the administrator at the beginning of the academic year.

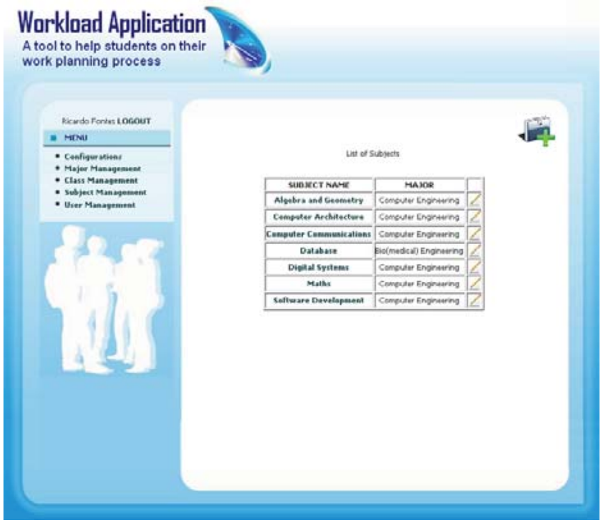

Figure 5. Graphical User Interfaces of the Administrator's back-office to define subjects of a cource

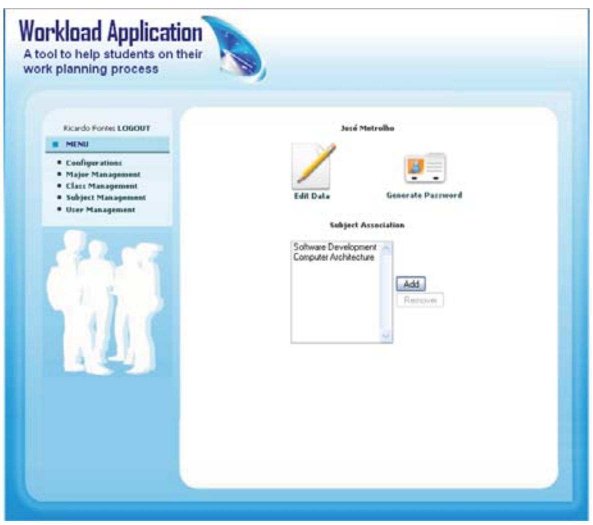

Figure 6. Graphical User Interfaces of the Administrator's back-office to edit data about a teacher's profile

IV. Conclusions

This paper introduces a web tool to allow better assessment and workload distribution along a Semester. The tool was designed to face the new goals that are present for teachers that work with new methods that are fostered by the Bologna Treaty implementation. This is the case of computing, programming, communications or embedded systems, amongst other courses.

In our opinion, this tool can also help course administrators to improve the effect of other initiatives (talks, workshops, tours, short courses, among others), without compromising the performance of student on their scheduled work for other course subjects. This view of the time table can lead to a better organization of extra activities in periods that do not compromise the students work production.

Another feature is to improve the students' organization skills.

The contribution is to improve the student's performance and not to impose limits to the number and difficulty level of their workload. The number and difficulty are responsibilities of the involved teachers, so the system doesn't have means to impose limits. The system just gives to the users an overall view about all the demanded workload, this information can then be used to achieve better results by smoothing the student's workload as possible, through a correct work planning.

The tool will be used in the next semester and the expected results are: improve the course(s) coordination; improve the work balance; improve indirectly the work's quality; improve the student's success rates, improve the student's grades and improve the impact of extra activities. In terms of software application we pretend to improve the application based on user's feedback, make available the application to be used by colleagues of other Institutions, and improve the design of the GUI. Actually we are implementing, as ongoing work, and advisor module (alert about the deadline approach by email for the registered students and teachers).

Acknowledgment

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Session 07B Area 3: Knowledge and Competencies Management - Knowledge

Knowledge Management and organizational learning University-Company - Learn to Learn

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Universidad Distrital Francisco José de Caldas (Colombia); Universidad Distrital Francisco José de Caldas (Colombia)

Approach to Teaching Communications Systems by Collaborative Learning. Student Perceptions in the application of Problem-Based Learning.

Antón, Miriam; de-Castro, Carlos; de-la-Torre, Isabel; Díaz, Francisco Javier; Díez, José Fernando; García, Enrique; López, Miguel; Sainz-de-Abajo, Beatriz

University of Cordoba (Spain); University of Valladolid (Spain)

Platform for teaching of location technologies based on Zigbee Wireless Sensor Networks by learning-through-play theory

Alejos, Ana Vázquez; Gay Fernández, José Antonio; Gómez, Iñigo Cuiñas; García Sánchez, Manuel

University of Vigo (Spain)

Adapting the Telecommunication Engineering curriculum to the EEES: a project based learning tied to several subjects

Antón, Miriam; Boto-Giralda, Daniel; de-la-Torre, Isabel; Díaz-Pernas, Francisco J.; Díez, José Fernando; González-Ortega, David; López, Miguel; Martínez-Zarzuela, Mario; Sainz-de-Abajo, Beatriz

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Knowledge Management and organizational learning University-Company

Learn to Learn

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Abstract— **this paper has information about the elaboration process of a knowledge Portal based on the relation between university and company. During this process, a study about knowledge management technologies was done to guaranty that the knowledge-life-cycle will be present in the relation between Universities and Companies; it could be implicit or explicit knowledge. One of those technologies used were knowledge management models (we present an alternative knowledge management model focus on University-Company), knowledge maps to identify and locate the knowledge present inside the organization. Theoretically the contribution of Eduardo Bueno [1], gave us a support to set the model based on his proposed model Intellect.**

The Project was proposed as a solution to the detected problems because of the lack of communication between University and Company. One of the problems that we found was social problems and others were technological problems, both of them appear as a result of the economical crisis around the world.

Keywords-component; Knowledge Management; Knowledge Portal; Organizational learning; TICs; University-Company; knowledge maps; knowledge management model; Web 2.0.

I. INTRODUCTION

The Project was proposed as a solution to the detected problems, caused because of the lack of communication between university and company. One of the problems that we found was social problems and others was technological problem; both of them appear as a result of the economical crisis around the world. So, it is important to create a different way to solve this problems, identify problems and solve it in order to improve human conditions should be the principal goal inside research groups. Moreover, if company and universities united their efforts to apply these solutions, it could be an economical change.

The current crisis, produce unemployment talking about the people who had just graduate or the amount of company that become bankrupt because of the lack of innovative process, products and services that allows them to be competitive in the rising marketing. However, inside the university there are innovative developments of products more specific inside research groups. Sadly, most of the times, these products are not use properly and became obsolete.

These products could be implemented inside companies so that they can generate innovative products and services in order to be competitive. So, the purpose of this project is divided into two different goals, they are: set a new knowledge management model (UNEM "Universidad- Empresa", that identify the knowledge every person in the organizations has and its behavior, it means, how it knowledge is use inside the organization to generate utilities, new process or create new products and services, developing a Knowledge Web Portal supported by a robust standard (J2EE "Java 2 Enterprise Edition"), with implementation of different tools of Web 2.0, among other systems that allows the interaction between the portal users, as well as easy share information, such as, products and services of companies and research groups of Universidad Distrital Francisco José de Caldas. Based on a model that was proposed, the idea is use knowledge management to change the organizations (University-Company) minds and made they learn to learn of themselves.

Also, is important that University and companies understand the importance of communication between every single person in the organization. This Project is a technological alternative to the organizations that really wants learn to use existing resources and learn to generate strategies and opportunities to the members, talking about Universities, students, teachers and researchers [2].

Knowledge management allows manage human resources and streamline processes within the organization. It detects the knowledge and finds the way to used it for all people and then generates new knowledge. There are a tool that allows Knowledge management applies models, is known as a knowledge portal, it is a way to organize all the information in order to be presented easily to the community and also be used in the best way, improving organizational processes.

Within its functions knowledge portal allows easy communication between portal users.

A problem that we found in our research was the lack of communication between Universities and Factories. Communication must be the principal challenge inside organization who wants to apply a knowledge management model. It could be the way to learn from the organization. But also, is the way to create new innovative process.

Being the knowledge that the persons possess one of the most useful resources inside the organization and the society and a different resource from other resources with which an organization arranges (land, machinery and capital), often it is not taking into account, for this reason it becomes obsolete in certain time. That is why there is a need to manage this knowledge. But first, it is important to identify where the knowledge is and who is the owner. For that, it is important to use knowledge maps and try to do it as personalized as possible. Once the organization has a map with all the information about knowledge they have it is important to share this knowledge but also identified what is the knowledge that the organization do not have it means identify the what kind of knowledge is needed. It could be the way to improves dramatically the organizational processes.

From the university and the company perspective, knowledge is constantly developing and it is necessary to identify it, use it, adapt it and disseminate it to obtain new knowledge that can be used for the organization (both University and Factory) and the people inside this one.

Within the developing process of the portal was performed an organizational analysis at the University and Company, to determine these critics nodes, as well as actors and sources of knowledge. It was also established the role of each of the nine players with which the portal counts, it was identified the concerns of each organization to establish contact and other content for the portal. Having identified the nodes were raised following the development of the subsystems to solve the different problems found, within the subsystems are: i) registry Subsystem, ii) Storage Subsystem iii) Research Groups and Companies Subsystem iv) Aid Subsystem v) Communities Subsystem vi) News Subsystem vii) Interaction Subsystem viii) Training Subsystem ix) External Links Subsystem x) Manager of employment Subsystem.

After the subsystems raised with the help of knowledge management model and the knowledge maps, facilitating the process of bringing it to a web environment, thanks to the implementation of J2EE specification and other development tools such as PostgresSQL (base engine data), JBoss (application server), which finally allows interaction and feedback from players whom are students, teachers, director of research group, factory director, company staff, factory, research groups, students and Administrators of the portal.

It is important to understand the role of technology inside organization (Neyra, 2006) [3]. If an organization wants to be competitive need to use technology. Also it is important for organizations to understand the importance of knowledge or know what they know [4].

II. KNOWLEDGE MANAGEMENT

A. *KM Historical Review*

Knowledge Management is used from unmemorable times, even in the migration of the people, the different cultures and knowledge they were shared and then different cultures arose, also we see it in the debates, meetings of the people, meetings, workshops, conferences, all these are ways of manage the knowledge, the idea of this one is to do that the knowledge that the persons possess will be transferred to others by the intention of creating new knowledge [5].

Though the term of management of Knowledge is relatively new already different sources of information exist where we can find information of this one. The management of knowledge has been present in the organization during already a lot of time ago, but it was known as the analysis organizations, the difference is that the knowledge management allows us to know the company, gives us the basic points to take the knowledge that the organization has to turn into new knowledge and of this form to achieve that strategies appear to future.

The Knowledge Management is so a useful term for the organizations and nowadays all with different modalities, to be able to capture and carry out all the processes of the knowledge inside the organizations, inside these we find the Knowledge Portals [6]., without leaving behind other technologies that are implemented at present as well as mobile applications applying Knowledge Management and the production of knowledge maps for each of the users of the portal, already there exist users who alone wish specifies information, for this the knowledge maps are useful to identify that a person possesses some kind of knowledge and since this one can be transferred to another person who needs it.

B. *KM Concept*

Knowledge management is defined ace all activities taking place inside an organization to uses, audience share, and develop the possessed knowledge by individuals within the same order that they ploughs geared towards obtaining the best aims of the organization. To implement the knowledge models we uses different tools to develop Web portals such ace the site of which we speak in this paper whose name is UNEM.

To knowledge portal is that one that establishes to relationship between people who access the knowledge and the knowledge that have been established at to steal when in the Web for the benefit of an organization.

To foster this relationship between users and portal, this latter count with the help of forums, chat, and definition, sometimes virtual communities interested in sharing and feedback to obtain a new knowledge based on knowledge already possessed.

A knowledge portal structure must suppot the life cycle of the organization allowing it to be able to continue with the cycle of knowledge and finally the publication of knowledge. Therefore, a knowledge portal is an influx of information, knowledge and applications through Web.

The portals are an essential component of a knowledge management model and knowledge itself, since it is one of the means used for the transmission of knowledge that is captured through the processes in each of the models.

They come with the aim of ensuring that knowledge comes in a timely and clear to the users ones they require it in certain moment. The portals allow the user access and allow for the exchange of information.

A knowledge portal specializes itself in a topic, so that this should be dealt in depth, thus providing full coverage and led to a community of users.

In the current world of set up of new virtual companies the representation of knowledge portals is something fundamental in this step, providing a point of personalized access to optimize the power supply decisions. Not only virtual enterprises enjoy the benefits of a knowledge portal in general all organizations can deploy using them to improve productivity by innovating organizational processes.

ICT (Information and Communication Technologies), make this kind of technology very broad allowing them to be implemented with a number of tools; this concept is too wide because the knowledge management philosophy are not even institutionalized. Now with the help of ICT is not necessary that the exchange of knowledge is in person or to obtain necessary information by going to the office branch of the organization, these new technologies enable the digitization of information by making it easily accessible and allowing a easy communication through chat rooms, forums, blogs and wikis.

C. Importance

The knowledge management is useful for all and each one of the organizations, because according to the knowledge management model which is defined the innovation of the processes is guaranteed inside the organization that will meet reflected in the increase of utilities of the organization, thanks to the optimization of the processes of knowledge.

For the implementation of the knowledge management model technology puts to our scope the tools that facilitate this process in an Web environment doing that the users of the portal could know all knowledge process, doing that it contribution to the company is every time better in terms of profit. It is necessary that the persons know the organization.

III. DESCRIPTION OF THE SOLUTION

One interesting thing about this research project is the model that we create. In order to create the model it was necessary made a knowledge map. It is an important tool to identify not only the knowledge that the organization has but also the one that it do not has. The map also shows the different roles inside the organization, it means that doing the map helps us to know who has the knowledge. Fig. 1 shows a resume of the knowledge map.

Once the map was done, there was necessary to create a Knowledge management model, to guaranty that the process of knowledge succeed in complete their cycle. Nonoka [7], presents the important of make tacit knowledge explicit, that is the way that process that knowledge have to do.

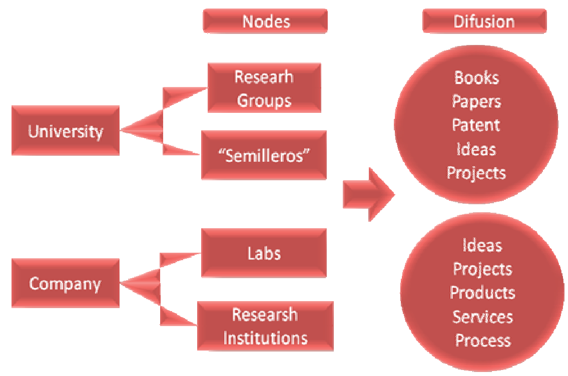

Figure 1 Knowledge Map (Resume)

Also, the knowledge portal was developed on a technological platform that was studied and considered to be appropriate for its implementation. Talking about the programming part we employed the standard J2EE because it give us a business environment and an application handles multilevel to give more safety to the application; this sort of standard handles the persistence cap, the logical cap and the cap of presentation of an independent way but each one connected with the previous one.

To handle the persistence of information we rely on the help of the Engine of Database Postgresql-8.1.3 that facilitates the managing of the information of the users, the portal as well as the information of the groups and the companies associated with the portal.

And finally as applications server we used Jboss-4.0.2 which supports the functioning of the application in the Web. The server is mounted on Operating system Linux.

The platform technology is necessary to implement the model of knowledge generated after the organizational analysis, the study of knowledge management in addition to the mapping of knowledge. This has a friendly user interface that allows people to put participants in the processes of knowledge and continuous creation and transfer of knowledge present in person the most important resource of the organization.

All the tools created in the portal born as a result of the knowledge model and try to solve the problems of knowledge inside the organization detected in the knowledge map.

IV. METHODOLOGY

In this section we will explain the methodology used for the elaboration and afterwards putting in action the Knowledge Portal to foment the relation between the University and the Company in the Electrical Sector, the general methodology is described in the following table.

TABLE I General Methodology

Stage	Description
Analysis of the organization	Inside this stage the organization is known, and there are identified the sources of knowledge and the nodes of the organization. It is important study the organizations looking for the organizational learning [8].
knowledge Management	There is guaranteed that there are fulfilled the processes of knowledge management. Inside the processes of knowledge that we find; apprehension, organization, to share, to learn, to apply, to evaluate. The necessary thing here, is to guarantee that is learned and the knowledge is applied for the approach of strategies .
Functional scheme - knowledge management model.	In this stage the model of km appears. That must satisfy the needs of the company and allow that the processes of knowledge should be fulfilled totally. In order that the platform will be as ideal as possible.
Technological platform	This stage is the Model implementation of KM in a Knowledge Portal working in the Web and fulfilling the knowledge processes, doing of the organization an entity that learns constant.
Implementation	After the developing of the portal it is necessary to do the assembly in the Web, in order that it is used and evaluated by the direct users. In order to improve it constant.

For the elaboration of the Knowledge Management Model an analysis of the organization was realized in order to guarantees to know all the sources of knowledge inside this one, as well as the selection of the knowledge, it is necessary because there exists knowledge that odd is useful to the organization. This model is a general scheme of what must form of the application Web.

In a general way, fig 2 describes the knowledge management model, the result of analyze University and Factory. It shows the principal systems to develop in the portal, also shows the nodes or the different roles to use the portal, also the portal describe the source of knowledge inside the organizations (University and Factory).

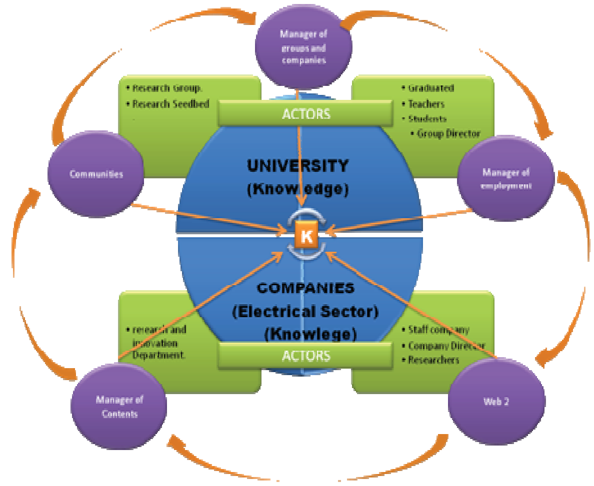

Figure 2 Knowledge Management Model

There are different models but this model is based on postulates of Eduardo Bueno (Bueno, 2004), who talk about the knowledge as an active of the organization as well as Human Capital [9].

A. *Organizational Analysis*

In conducting the analysis within the Organizational and Business University different active nodes were identified, among which are; with sub-nodes University Research Groups and Seed Research, the Electricity Sector Enterprises. The first node includes a University subnodo very important for the development of the knowledge portal for Research Groups and Seed Research who are the largest producers of knowledge within the university, it is clear that within these nodes are located; students , Head of research groups or seed, faculty, alumni, we consider them as producers or makers of knowledge. The second node is detected the Enterprise around which argues the knowledge previously acquired through practice.

B. *Knowledge Management*

Inside the frame the knowledge management, persons are the most important resource of the organizations.

The most important within an application within the parameters of knowledge management is to ensure compliance with the various processes of knowledge that make this a tool for creating innovative processes within organizations that apply its principles.

Among these are: Organization, Sharing, Learning, Implementation and Evaluation. Within the knowledge organization the most important thing is to identify the sources thereof within the organization and thus able to make a classification and identification of obsolete knowledge within the organization, this process may be known as discovery of knowledge.

Sharing knowledge is the principal key in knowledge management process that ensures that knowledge is not lost, because it must be owned by each members of the organization, without running the risk that this is own of a single person, on the dissemination of knowledge makes this knowledge better.

Once knowledge is disseminated by different means (between which the portals of knowledge stand out), this should go through a learning stage, the learner must assimilate this new knowledge and apply it to ensure that the transmission of that Knowledge was a success.

As the object of knowledge management is the optimization of the processes within the organization which generate innovative models within the same, it is at this point in the process of understanding where they should strive to achieve this goal. The process that describes this innovation is the application of knowledge within the organization, with the knowledge has been gained from it, to ensure the implementation of innovative schemes to the organization, the result of the analysis of knowledge was present among the people in the organization and making it possible to satisfy the different processes.

The last step is the evaluation of performance and existing knowledge; it is worth clarifying that the processes of knowledge describing a cyclical pattern, the processes must be in continuous motion.

V. RESULTS

The results of this project are the implementation of the Portal in the Web, which contains the information of the associate companies and the research groups of the university, besides different systems that give solution to the problems found by the lack of communication between the companies and the University.

The portal allows that the processes of knowledge should be fulfilled in a suitable way and that the creation and transference of knowledge will be in a cyclical way, guaranteeing that the processes implemented in the organizations are innovative in all the aspects. In Fig 3 we can see the results of the different subsystems of the portal. The final Portal is known as a UNEM because of its Spanish meaning (Universidad Empresa).

Currently the portal is been proved. One company of the electrical sector is helping us to prove the portal; this company is working with the "Universidad Distrital Francisco Jose de Caldas", which is the University where we developed the project. There is a huge communication problem and with this project we are trying to solve it. However, it is a long process in which the portal is going to change according with the necessities.

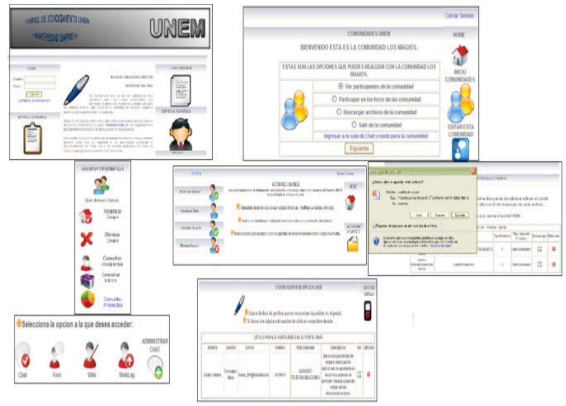

Figure 3 Project Results

This project will raise the design of a knowledge portal that allows users to interact and most importantly allowing users of the knowledge portal to access information in an easy way and search for information more effective. It portal has the following subsystems:

- Registry Subsystem: allows the management of users in the portal to facilitate the collection of contact details for them.
- Research Groups and Companies Subsystem: It allows the information management of groups and companies.
- Aid Subsystem: It allows browsing by the portal is easy.
- Communities Subsystem: The communities that allow users interested in specific issues, easily find information on this, in addition to being with others who know the subject.
- News Subsystem: Este sistema permite la comunicación de noticias y eventos a todos y cada uno de los usuarios del portal.
- Interaction Subsystem: It is one of the most important systems because it allows the permanent communication between the users of the portal.
- Training Subsystem: thanks to Moodle can be programmed courses for University or Companies.
- External Links enables users to include links of interest.

VI. CONCLUSIONS

There is not a unique knowledge management model, because the companies internally are different, so it is necessary to do an analysis of the organization in order to know the functioning of the organization.

The most important resource of the organizations are the persons specially their knowledge, so it is necessary to find the way of implementing systems that allow that the persons should interact in order to guarantee that the processes of the knowledge are implemented satisfactorily.

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The elaboration of the knowledge management model allows identify which are the nodes to take into account in the knowledge portal.

Wikis and blogs are very simple but also very powerful tools. If you managed it well, it could be fundamental engines in the knowledge management talking about the organizations.

It is important for organizations implements knowledge portals if they want to improve the internal processes.

The knowledge portals are indispensable in the organizations that want to improve the internal processes.

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Approach to Teaching Communications Systems by Collaborative Learning. Student Perceptions in the application of Problem-Based Learning.

Analysis of results

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Abstract—**This document reflects the results of the study at the end of the course, which justify how the application of problem-based learning and collaborative learning help the student to take on board in the most appropriate way the study material. An analysis of the results of the surveys carried out amongst those students learning Communication Systems in Industrial Technical Engineering was undertaken, in order to evaluate whether the application of Problem-Based Learning (PBL) methodology together with Collaborative Learning (CL) was likely to improve the rate of development of their ability indispensable in today´s business world, and also to achieve those objectives set out in the course. By far the majority of students showed a very positive attitude towards this methodology, their objections being very limited. A comparison was carried out with the results of those courses of a similar nature at the University of Cordoba, as was the attitude of the students towards this new methodology, with very comparable results.**

Keywords- collaborative learning, learning management system (LMS), problem-based learning (PBL), communication system, education.

I. Introduction

Despite educational methods have changed over the years according to the results (successes and failures) that the system imposes, as teachers we must find a way of looking at the challenges our future engineers face, using new ideas, developing their creativity in such a way as it improves their own knowledge and that they learn the study material at the same time as resolving a problem or proposed project. If, to this way of constructing knowledge using the problem-based learning method (PBL), the achievements of which have been collected in various bibliographical reports, we add collaborative learning to develop the intellectual capacity and the social skills of our students through interaction with their colleagues, as teachers we will have achieved two very worthy objectives: that of giving them knowledge and of providing them with a range of abilities for their future professional development.

Although it was in the Faculty of Health Sciences of the University of McMaster, that the new educational system now known as PBL was established in the 60s [1], this methodology has since been implemented in both primary and secondary education, given its demonstrable efficiency, thanks to the numerous publications that praise the positive effects of its implementation in engineering courses [2-4].

The use of Moodle, a learning management system (LMS) adapted to the course, contributes to interactivity and the meeting place of our students outside of the classroom, so important for this cooperative learning, the philosophy of which is based on development and analysis.

II. The Main Objective

This article is based on the analysis of results obtained from the students of the final Industrial Engineering course, following the application of the teaching method Problem-Based Learning (PBL) using Collaborative Learning (CL).

Communication Systems subject is elective subject undertaken during the last term of the last year of the Industrial Engineering, Industrial Electronic speciality, degree. Its aim is to analyse different systems for high speed Internet accessing. Most of the students arrive with any knowledge of this matter, due to they come from the area of Industrial Electronics.

Due to the use of both the PBL and the CL, the students develop the learning process in groups by the project solving, achieving the subject goals by experimenting and searching information sources. This methodology helps the students to understand and assimilate the knowledge through the use of basic assumptions versus the conventional method used previously mainly based on the master class. In the PBL method, the problem is first presented to identify the learning requirements and then it is essential the information-gathering process to, finally, return to the problem. Hence, the learning process is reversed. The foundations of the PBL methodology are the Cooperative Learning and the Constructivism, where the students acquire skills through problem solving.

The advent of the modern knowledge society requires changes in educational processes [5]. Everything seems to indicate that the PBL method is a better way of imparting education in communications systems, or even technology in general. PBL course students learn social skills through interaction in small groups, how to identify and define a problem, and how to look for and filter out relevant information [6]. PBL promotes engagement in meaningful learning and cooperation among students [7]. In the same way, collaborative learning changes the structure of learning in the classroom, permits interactions and makes easier and develops basics skills such as dialogue and solidarity, amongst other things. The methodology and its application for education in communication systems will be discussed in this paper.

Despite a wide-ranging bibliography which defends the positive results of the application of these methodologies, as investigators we are bond to question whether it is the most appropriate method for our engineering students, given the recent nature of its implementation in the course and the fact that as human beings we are naturally slow to adopt new ideas. Because of this, using a series of surveys, we managed to discover how people felt about the implementation of this method compared to traditional teaching methods, taking into account the final results of the evaluations of knowledge gained and cross-referencing abilities.

III. METHODOLOGICAL APPROACH

A survey at the end of the course showed that students were satisfied with the pedagogical approach. These results are based in a questionnaire with four items, where the students are asked about the effectiveness of the method applied during the semester versus the traditional method (master class) to attain the subject goals. The interrogated students were a total of 22. The contribution was compulsory and anonymous. The students take an average of 10 minutes to answer the questionnaire. The opinion of the students, allows us to tell whether this methodological practice is the most appropriate for the teaching development of the communication systems course, taking into account not only the assessment of the students involved, but also the final academic results of the students compared with the course records, which allows us to demonstrate objectively how the application of this methodology obtains better learning results, not only at an academic level, but also in the way the student is more involved in the learning programme and gets from it greater personal satisfaction. The knowledge evaluation carried out on the students, in terms of end exams, shows that there was a significant difference in the knowledge gain. The skill sets acquired were definitely greater than those acquired by the students of traditional education as was demonstrated by the results of the skill test conducted at the end of the course.

Following analysis of the observations made by the students, we can divide the evaluation of the methodology into Very Positive, Positive and Negative. Table I shows the results with the corresponding percentages.

Following are some of the comments made by the students in defense or rejection of the new methodology (Table II).

IV. ACADEMIC RESULTS AND OBSERVATIONS

Many questions have arisen and for the most part they have been assessed favourably. Equally, a small percentage shows up of students who continue preferring to develop their work in an individual way, believing that their final results will be better. The rejection by some students of the methodology in the initial phase of its application has already been described by Felder [8].

Looking at these results it can be claimed that despite the recent application of the method in the course, the Very Positive evaluation is overwhelming, in the students words "interesting", "engaging", "dynamic" working in a collaborative way in the development of the PBL methodology, favouring the exchange of opinions with those with whom they had not previously worked, given that the those people making up the groups had been chosen arbitrarily by the professor. Many underline the importance of working in a group as being a stepping stone in the way they will inevitably develop their professional careers.

TABLE I. PERCENTAGE OF EVALUATIONS

	Percentage
Very positive	63,6%
Positive	27,3%
Negative	9,1%
Total	100%

TABLE II. ARGUMENTS FOR AND AGAINST THE APPLICATION OF THE METHOD ACCORDING TO THE POSITION OF THE STUDENT.

	Arguments for and against
Very positive (63,6%)	It is an interesting method which allows for the expression of contrasting opinions, unlike traditional teaching methods where the opinion of the professor is the final word and we the students must accept that. It is more engaging being able to exchange ideas and participate. The class is more dynamic. It is a good method for interchanging ideas. It allows you to listen to the opinions of others and compare ideas. It makes you think and it is easier to retain information. Because you work in a group, the class is more active. It brings benefits such as being able to work with class-mates. One learns the opinions and proposals of ones class-mates. It is easier to understand certain things when a class-mate explains them.

	Working as a team has made it easier to resolve problems. It allows one to share the different view-points of the whole group, to learn to fit in and to work as a team. I would do the same thing again in other courses.
Positive (27,3%)	It is a very good methodology but sometimes one works better alone. Working as a team is good when all of the group members pull together. It works well when there are few people in the group, but it is better working alone when the groups are very big, given that it is much harder to make headway when so many have to be in agreement. Not all the group members put in the same amount of effort. It is a good method, but not necessarily for the entire course. Sometimes it is good to have a traditional theory class.
Negative (9,1%)	I prefer working alone. I don´t feel comfortable. I prefer the traditional method.

The students point out the fact that working in a group and with their classmates explaining certain concepts (and therefore those they consider as equals), helps with understanding and retention.

There is a certain group of students who, despite showing a positive reaction to this type of apprenticeship, allege that the application of this methodology requires more time to develop the activity than that of traditional teaching methods. Others claim that the student only really understands the part they have worked on, which shows that they do not understand the philosophy of this methodology, the point of which is that all the students achieve the objectives laid out in the course through the development of the problems or projects put forward. The fact that no one component part of the group is able to provide an adequate solution to the problem may be a negative factor in the development of the work. Finally, the lack of involvement of some of the members may also unbalance the work of the other component parts.

Amongst the negative opinions, that which stands out for a small minority of students is the refusal to accept the changes in methodology and the simple fact that the implementation of PBL involves dedicating more time to and being dependent upon a group of people who perhaps are not committed to the activity, undermining the end results.

Following we show the academic results compared with those of the two previous courses (see Figure 1, 2 and 3), in order to highlight the effectiveness of the application of the method in a teaching environment, given that the ultimate purpose of pursuing its application is to show the level of effectiveness of this methodology. It is important to point out that the enrolment number were 20 in 2006/2007 and 23 in 2007/2008.

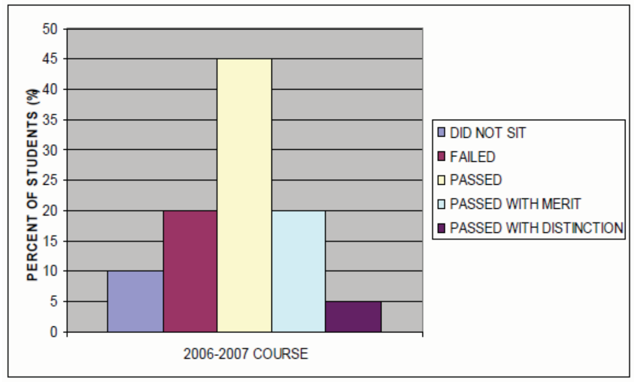

Figure 1. Results of the student evaluation: overall grades (2006-2007). University of Valladolid, Spain

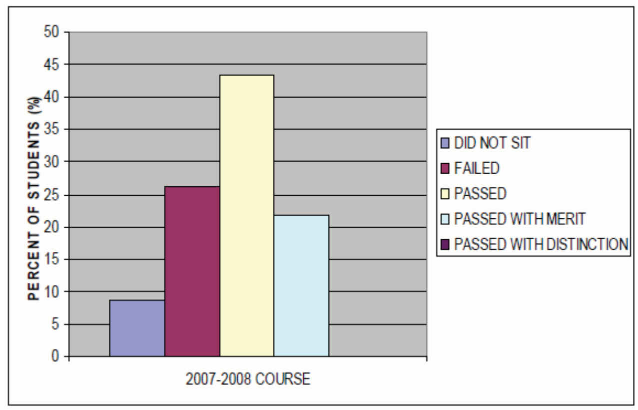

Figure 2. Results of the student evaluation: overall grades (2007-2008). University of Valladolid, Spain

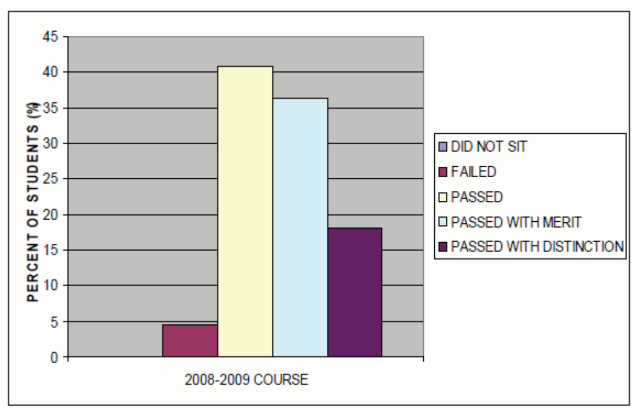

Figure 3. Results of student evaluation: overall grades (2008-2009). University of Valladolid, Spain

V. CONCLUSIONS

Thus, this article reflects the results of the study which justify how the application of problem-based learning and collaborative learning help the student to take on board in the most appropriate way the study material and improve their social skills. The social skills gaining were also observed by the students. They admit through the survey that the group working let them share, integrate, and even learnt to work in group and to listen to others, better communicating their ideas.

From this information it is obvious the need for a change in the conception of the teaching-apprenticeship process, although this does not necessarily imply that the traditional classroom environment no longer has its place. What stands out from the gathering of data is how the joint application of these methodologies is generally well-received by the student. The fact that the surveys were carried out anonymously leads to the belief that they are valid and the fact that the grades of the students have improved considerably, confirms once again what the studies have demonstrated in accordance with the application of this methodology: its effectiveness in the appropriate development of conceptual and cross-referencing skills of those students taking engineering degrees.

It is also worth noting that the statistics of this study have been compared with those of degree courses of a similar nature in the field of engineering, of the department of computing and numeric analysis of the University of Cordoba, where the PBL methodology has been applied in a similar way, together with collaborative learning. We appreciate an improvement in the final grades in both Universities (see Figure 4 and 5).

We can also see a high level of satisfaction amongst those students questioned about the benefits of this new way of acquiring knowledge.

We believe it would be interesting to extend this study to different courses and degree subjects, with the idea of soliciting the opinion of the students of this technique for the different subjects of the study, given that it may not be so easy to apply.

The results could differ according to the contents, adapting the most appropriate methodologies to each course to gain the necessary skills. Only by finding the most appropriate method using the feedback of the interested parties, we will be able to obtain the best results and the highest level of satisfaction amongst students. As professors we must take into account the opinions of the students with respect to the methodology which sparks the most interest, motivates and improves results.

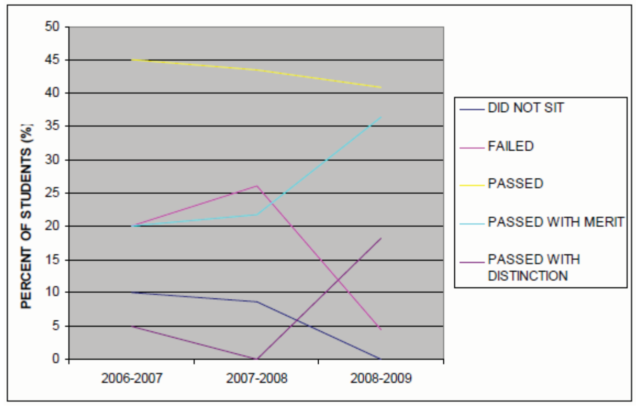

Figure 4. Improvement in the final grades. University of Valladolid

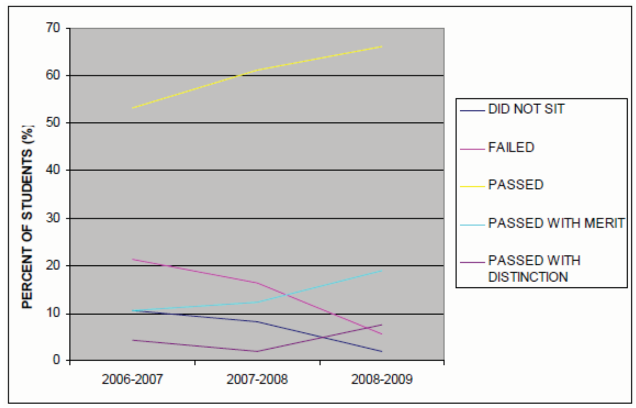

Figure 5. Improvement in the final grades. University of Cordoba

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Platform for teaching of location technologies based on Zigbee Wireless Sensor Networks by learning-through-play theory

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Abstract—**In this paper an experimental Wireless Sensor Network (WSN) platform is introduced as an aid in teaching location techniques based on RSSI (Received Signal Strength Indicator) in the frame of a an radiolocation course at graduate level. The platform is implemented using low-cost commercial modules and one easy-to-use software program. The teaching methodology tries to develop the *learning by doing* theory and it is completed with a final practice that implements the *learning-through-play theory*. Both techniques have resulted in positive learning outcomes by enhancing the student role in the learning process.**

Keywords- learning through play, learning by doing

I. Introduction

The development of innovative material as well as new methodological approaches will be a demand in the new study plans that incorporate the European Higher Education Area (EHEA) requirements for the imminent future of European universities.

The introduction of new teaching-learning methodologies in classical areas as engineering has found large reticence mainly due to some risks supposed to innovative methodologies, such as loss of contents, incorrect timing dimensioning, not enough number of resources (labs, material …) These and other lacks have discourage instructors.

The use of active learning methodologies results largely suitable for the teaching of technical disciplines since they facilitate that students learn both engineering processes and content knowledge. Simple experimental tests can facilitate the acquisition of most important concepts that students will need to use and apply as professional engineers after the graduation.

In this paper we present an educational platform for approaching the teaching of wireless technologies. For our case, the 2.4GHz band was selected, due to its unlicensed feature and the interest of actual applications developed in this frequency, especially the wireless sensor networks and the use of them for location and tracking applications.

Similar experimental systems have been previously developed regarding WSNs [1, 2], but they can be also found in the field of electromagnetism teaching as [2-8]. In [2, 6] we can read the importance of the instrumentation in the radio courses curriculum and how the RF instruments and experimentation can help to emphasize signal and system theory concepts to students. In [7, 8] cost-effective solutions are implemented to design educational modules used in wireless communication courses showing a good performance.

In our case, a commercial kit has been used to deploy a WSN. The system was completed by programs developed in MATLAB software. This allows planning different experiments focused on the main concepts related to location estimation based on RSSI technique, as well as routing in a Zigbee network.

One initial practice will introduce students in the deployment of a Zigbee WSN, the location estimation according to the RSSI measurement and triangulation principle. The experiment has as goal to achieve the full operation of the WSN and the real-time estimation of the user nodes, tracking their positions by using the specific software tool.

After this a challenge is developed as a practical implementation of the *learning-through-play* theory: the TUs are randomly activated and distributed all over one indoor scenario, and the student teams have to determine which one of them are active and their corresponding positions.

The first application of the system here introduced was for the development of two Master Thesis that finally achieved one conference publication [9]. In the present paper we introduce the first year of the experience, a pilot version carried out with a small group of twelve students offered as volunteers from the total of students registered in the course.

In section II we introduce the theoretical background of the teaching experience. The developed teaching methodology is explained in section III, including the implementation. Finally, in section IV, we present the evaluation method followed to infer the progress and success of the experience. In the last section, we offer the conclusions to this research work and indicate some ideas for future work.

This research work was supported in part by the Xunta de Galicia under Grant CO-199-07.

II. ACTIVE LEARNING IN THE CLASSROOM

Traditional lectures are the more extended teaching method that can be found in the colleges and universities. But in the last two decades this traditional methodology has suffered a clear evolution toward other forms of understanding the knowledge acquisition [10-15].

The development of material that incorporates active learning experiences is a challenge for the instructors that are not usually encouraged to face this step. Among other reasons, the EHEA process has determined the university and studies structures but not the training methodologies that should consider the use of active methodologies to improve the student learning process [16-19].

In this section we analyze two main methodologies that try to incorporate active learning teaching: learning by doing and learning by play. We have selected them among other ones due to the suitability to our goals and contents.

A. *Learning by doing*

The learning based on the experience, experiential, factual, "learning by doing" or "hands-on learning" is generally framed in the active learning methodologies. This supposes to encourage people to discover by themselves the principles of operation of the systems, processes, etc. through the experimentation and the exploration [20-24].

This kind of methodology promotes the construction of deep cognition and increases the comprehensive as well as the effectiveness and efficiency to put in practice the learned skills [21] according to a succession of stages as indicated in Figure 1. This feature is largely interesting to give the students a practical view for their imminent professional future.

B. *Learning through play*

Students must learn the fundamental concepts and the necessary skills to apply them effectively in a game-based experience. This methodology has been widely applied in computational and engineering teaching field [26-28] showing a large level of satisfaction, and becoming also largely effective at the cognitive level.

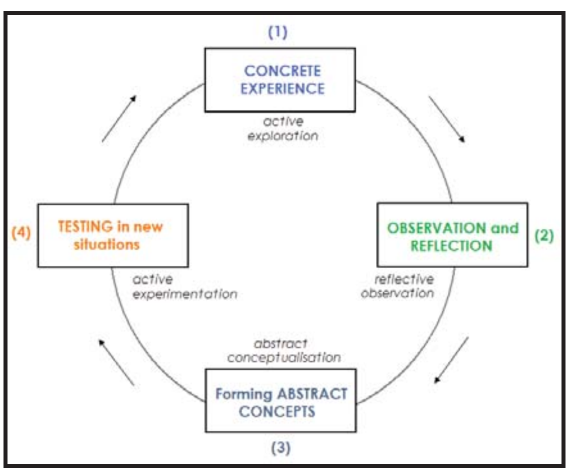

Figure 1. Stages in learning by doing (experiential) method [21].

III. TEACHING METHODOLOGY

The experience described in this paper tries to approach the teaching of one primary location technique that can be widely found in radio wireless applications. It is inscribed in the framework of the graduate-level course *"Radio determination"* offered in the last year at the Electrical and Computer Engineering degree at the University of Vigo, Spain.

This course is optional, so students decide to select it according to a criterion of the curriculum/profile that they desire to develop. Usually, students with specialization in radio select this course, but it is common also to find students from the networking or electronics branches. Among the criteria that students hold to select an optional course, the attractive offered by the course and the grade of update showed are factors playing an important role.

The contents of the course include radionavigation and radiolocation systems used in aeronautics and aerospace, as landing aid systems (ILS, VOR), or navigation aid (GPS, Galileo, GLONASS). The theoretical contents are given following traditional lecture classes, and lab practices have been designed according a learning-by-doing methodology.

In the last years, the radio location techniques are spreading the field of use and they are commonly found in many dairy applications. Some of the radio locations have become very popular thanks to the emerging wireless communications in unlicensed bands, especially the Wireless Sensor Networks (WSN) case have awaken a large interest due to the attractive features. The incorporation of Zigbee protocol offers additional value and facilities to these networks.

In an attempt to update, the course has incorporated the teaching of radio location techniques in the frame of WSN as a third block in the contents of the course, with theoretical classes and practical experiences.

But this technique can be hardly understood if only theoretical explanations are provided, and even if simulations are employed. On the other side, one objective of the active learning is to attract the attention of the students and keeping their motivation. A combination of learning-by-doing and learning-through play has considered the optimal solution to join both teaching and learning milestones.

In the following sections we present the resources that have been used and developed in this experience, and some details of the practical implementation.

A. *Resources*

Learning by doing experiences based in field experiences imply the use of material that sometimes is not covered by the general purpose instrumentation. The acquisition of specific educational material is large-cost and not usually affordable.

But many solutions exist in form of development kits available for the industry and perfectly valid for academic purposes. It has been our case, and we proceeded to acquire a Zigbee WSN commercial kit with the feature of estimating the power of the received signal. The core chip used by this kit incorporates the transceiver front-end as well as an 8051 core to program the user applications.

In order to implement a radio location system to estimate the position of a mobile user, three elements are mainly necessary:

(1) Reference units (RU) at known positions transmitting a predefined value of power. They act also as routing elements of the information transmitted from the mobile users.

(2) Mobile terminal units (TU) with unknown positions that estimate the power received from the RUs (Received Strength Signal Indicator, RSSI) and feedback this value to the master node (MN) using the network of RUs.

(3) Master node: in our case, this node is the responsible of estimating the TU position by triangulating the power received from it at the RUs. The triangulation implies the assumption of one radio mobile channel, one important concept of this experience besides the own triangulation technique. The MN is connected to a computer via RS-232.

In Figure 2 we show the three elements above described, and it can be shown that they share the same chip board. A brassboard has been designed for the TUs, containing one led-push button, reset button and one inclinometer. Sensors can be easily incorporated for future use.

Additional software elements have been designed to complete the material of this experience. The tools developed will facilitate to the students the development of the experience helping them to focus on the targeted concepts:

(1) Compiled C Code for RUs: it includes the functionalities of network routing and power message transmission.

(2) Compiled C Code for TUs: it includes the functionalities of network routing and power messages reception. Automatically selects the frequency channel of operation, and it recognizes the

(3) Compiled C Code for MN: it includes the functionalities of network routing and the serial communications with the computer.

(4) Student program: implemented in Matlab, it receives the data needed for the triangulation according to the propagation model.

The code corresponding to RU, TU and MN has to be uploaded to the core chip via JTAG programming tool as indicated in Figure 3.

The student program has become fundamental for the development of the experience. It provides functionalities to dimension the network, to assign a role to a board chip (TU, RU, MN), to fit the propagation model and to perform correctly the triangulation. In Figure 4 it is shown the main screen of this tool.

B. Implementation of the experience

A learning-by-doing methodology has been estimated as an optimal solution to present the *modus operandis* of real time positioning systems based on the estimation of the received signal strength. Firstly, a set of four short practices introduce the different objective concepts. One session of two hours has been assigned to each practice. Students elaborate one four-page report after the completion of the four practices.

(a)

(b)

(c)

Figure 2. (a) Master node (b) Reference node (c) Terminal user

Figure 3. Programming facilities.

Following we briefly describe the main milestones of the initial four short practices:

(1) Dimension the network and assignation of one role to the chip boards. Some parameters of the RUs and TUs as ID, and position (X, Y, Z) have to be predefined. In Figure 5 the node setup menu is shown. In Figure 6 it can be observed an example output of this practice.

(2) Test of communication: the different elements are activated and the network deployed in an actual indoor scenario. Test messages are routed among the nodes. A mesh topology is followed.

(3) Fit the propagation model: one main parameter of the propagation model has to be set: *N*. It approximates the power decay curve for the signal transmitted from one RU and received by one TU. This propagation model is commonly used in indoor scenarios, and as is called log-distance model. The accuracy in the estimation of *N* is deeply related to more accurate position estimation. In Figure 7 it can be observed the model fit menu.

(4) Triangulation: students have to implement the algorithm for position estimation based on the equilateral triangulation technique of received RSSIs.

The methodology is completed with one final practice that summarizes all the learned concepts and is valid to put in practice the skills learned and developed by the students. It is presented in form of through-play.

As an outcome of the initial practices, the students are in position of estimating the location of any TU, as well as the ID of the available RUs, in the deployed network always that the learning process has been successfully completed. So, in the next step they have to determine under blind conditions, which RU nodes of the network are working, how many TUs are active and also they have to determine the TUs location.

If the software tools have been correctly fitted, and a comprehensive cognition has taken place, the students will pass this challenge with less effort that if it is planned as a single practice.

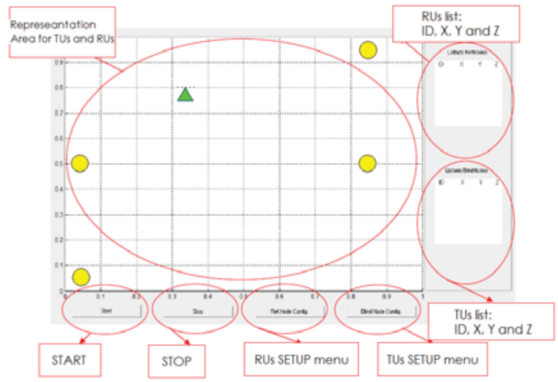

Figure 4. MATLAB student's interface program.

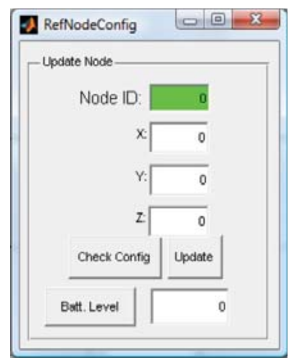

Figure 5. Node setup menu.

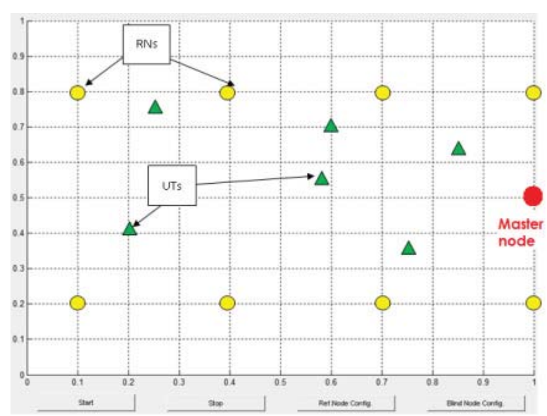

Figure 6. Geometrical disposition of elements in the Zigbee mesh network.

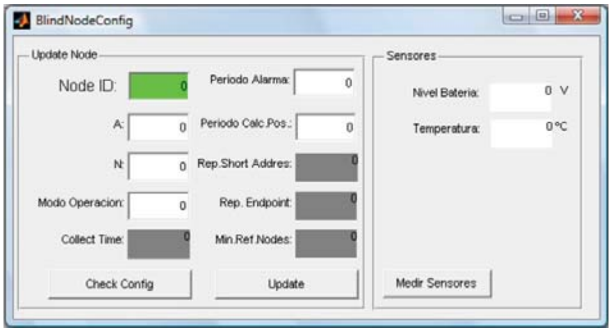

Figure 7. Propagation model fit menu.

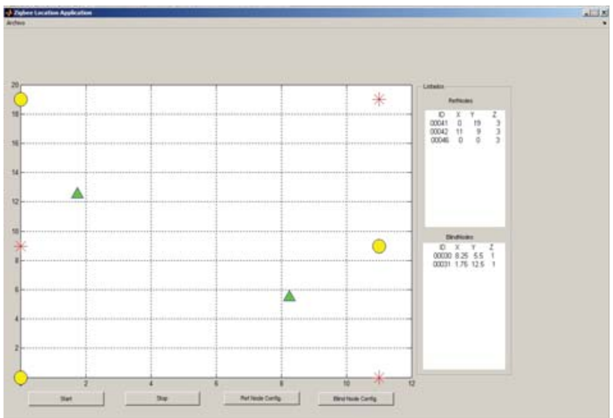

Figure 8. Example of final challenge scenario.

It will result useful in a double sense: firstly, it summarizes the concepts and skills object of this block of the course content; secondly, it allows the student a general scope of the technique here presented that can help to clarify some remaining doubts. In itself this challenge constitutes an auto-evaluation of the previously learned concepts. In Figure 8 it can be observed one example of scenario for this challenge.

IV. Evaluation of Results

Another not less important aspect to consider along the development of this kind of learning is the way of evaluating the acquisition of knowledge [29]. It is essential to collect information in the cognitive and in the affective dimension. This information has to be analyzed to evaluate a classical trade-off: the satisfaction level and the effective cognitive learning.

The evaluation of the subject was divided in two parts. The evaluation of the theoretical contents follows an innovative method based on online surveys provided via a web educational platform that uses the open source eLearning and eWorking platform *Claroline* [30, 31]. The surveys include ten short questions regarding the theoretical part. In Figure 9 we can see the home page of the website dedicated to the eLearning platform.

Figure 9. Screen shot of *faitic.uvigo.es* web.

The number of students attending the subject last year was 70. For the lab practices, they were divided in groups of two, and later assigned to one turn controlled by a different teacher. Three blocks of practices were designed, and the experimental experience regards block #3.

Volunteers were solicited to develop this pilot experience and a total of 12 students attended the call. A different task was assigned to the students that did not participate in the pilot group, consisting in a documentation work to be exposed at the classroom. These works were evaluated by the rest of groups.

For the evaluation of the other practical contents a traditional method usually extended in engineering was used, consisting in the elaboration of reports regarding the lab practices.

In order to evaluate the cognitive level, for each practice a set of questions are included in the memory to be solved and answer by the group. So, individual scores cannot be evaluated separately. This can result in an unfair score for students and does not reflect the individual effort.

A statistical analysis based on boxplot results a powerful tool to analyze the deviation of the individual, group and turn scores with respect to their respective medians. This simple analysis offers a good graphical inspection tool of influence factors as important as: teacher in charge of the turn, difficulty level of the practices. Students requiring reinforce can be identified.

Generally, for practical block 3, groups achieved larger scores in the pilot experience than for the documentation work. Among the reasons to explain this fact, we can remark that usually the level of effort is less in this kind of tasks and also the level of motivation. We have detected also that some of the works were identical to the last year. In general, the level of deepening in the topic assigned is not large and the students tend to minimizes effort and time. The result is that a 10% of the students fail this practice with scores under 5.

The success of the experimental practice can be explained also by the large level of control that the experience provides for its development. All the steps are predefined and the objectives are presented in a piecewise mode, from simple to complex levels, so it results in a straightforward progress for the student.

The satisfaction level was inferred from the surveys that our institution passes each semester to every subject. The surveys demonstrated a good performance in the affective dimension. This can be inferred also form the results of pilot experience scores.

V. Conclusions

After In this paper we have analyzed one pilot experience developed at the graduate level of an engineering degree. We can state that education has evolved from a teaching to a learning focus and the incorporation of active learning is the way for this transformation. Active learning based methodologies have demonstrated to be more effective than passive learning. We analyzed that the use of active learning methodologies results largely suitable for the teaching of technical disciplines such as engineering.

We conclude that simple experimental tests can facilitate the acquisition of most important concepts that students will need to use and apply as professional engineers after the graduation.

We presented the methodology developed and the material needed to carry out this practice. The pilot experience showed a large level of enthusiasm and satisfactory feeling among students.

In the evaluation method, it results necessary to implement a form of differentiating the individual and the group scores in the lab practices. The design of individual surveys may be a solution and it is of easy implementation thanks to the available eLearning platforms.

The good results achieved encouraged the teachers to repeat the experience next year trying to introduce some novelties thanks to the developed and tested methodology and the available material, as well as the experience acquired by the teachers.

Acknowledgment

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Adapting the Telecommunication Engineering Curriculum to the EEES: a project based learning tied to several subjects

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Abstract—**This paper describes the adaptation process to the European Credit Transfer System requirements of several subjects aiming at the Information and Communication Technologies (ICT) learning. Specifically, these subjects are sited at the Telecommunications Engineering studies lectured in the University of Valladolid. In a first step two first grade subjects have been established, while in a second and final step, coinciding with the new degrees beginning, it will be extended to five subjects placed in consecutive semesters.**

The global programming has been divided into several subprojects of growing complexity, developed into subjects sited in different and successive semesters of the degree, following a pathway leading to the development of a global project throughout four years. The whole learning process is ICT-supported, as tools for overcoming distance and scheduling barriers are offered. In particular, Moodle platform is used, which has been enhanced with self-evaluation and co-evaluation tools developed by the teaching group. Main innovation regarding to the classical approach consists of a computer programming subject focused on the student learning and based on the detailed specification of the activity the students have to perform in and out of the classroom in order to achieve the educational objectives of each of the subjects. The educational strategies used to accomplish these objectives are based on the cooperative learning, on the teamwork developing a programming project (Project Based Learning, PBL), and on the discovery learning.

Keywords: European Credit Transfer System; engineering subjects; Project Based Learning, Moodle platform.

I. Introduction

In the 50s, 60s, and 70s of the 20th century the idea about learning as a process of gaining knowledge is established. This process takes place when the student can permanently store new information in memory. In this model, the role of the student is to gain knowledge in a passive way, and the teacher's is to design environments where the student can receive a great deal of information [1].

As of 80s and 90s, the teaching idea is transformed into a concept of building up knowledge, which is performed when students directly participate in that building connecting new learning with the foreknowledge [4]. The teacher's task in this case is to design environments where important interactions among the students, the teacher, and the scholarly resources can be provided in order to let the student select, organize, and properly apply the new information.

The problem based learning, and its variant Project Based Learning (PBL), is a strategy which presents the students the challenge of "learning to learn" through the collaborative resolution of open problems, being guided by an enabler. That is, this methodology is based on a project or plan development following the project design approach. Activities are oriented to plan a solution of a complex problem. Work is performed in teams. The students have more autonomy than in a traditional class, they use different resources as the teacher is not the main source of information, he/she acts as an enabler providing resources and offering advice while they advance in their research. The students gather and analyze the information, make discoveries and report the obtained results. The teaching and facilitation are oriented by a wide range of explicit learning objectives; some of them can be precisely focused to the specific content of the theme. The students can achieve additional goals (no planned) as they explore complex themes along different lines; they learn to learn between them; they learn how to help their partners learning; they learn to peer-review and give constructive feedback both for them and their partners. Hence, the aim of the project based learning is to place the student in a realistic scenario, facing real-world issues, to initiate his/her learning process [6]. The PBL has been used in the university in general, and in the area of engineering in particular [5]. The project is the point which unleashes the learning process, and its development causes the knowledge structuring into modules grouping several traditional subjects. Therefore, this working practice depicts a consistent alternative with the teaching method needed for training professionals, especially technicians. This approach is also suitable, to a greater or lesser degree, in mostly every field of study.

II. BACKGROUNDS

In the 2005/06 school year we launched the adaptation process to the European credit system requirements in one of the subjects design for the Computer Programming learning – "*Fundamentos de Programación*"- undertaken at the Telecommunications and Electronic Engineering studies lectured in the University of Valladolid. Main innovation regarding to the classical approach consists of a computer programming subject focused on the student learning and based on the detailed specification of the activity the students have to perform in and out of the classroom in order to achieve the educational objectives of the subject. The educational strategies used to accomplish these objectives are based on the cooperative learning, formally structured by the puzzle technique, and on a teamwork development of a programming project of low-medium complexity level. This approach has been the result of the learning program adaptation of the Introduction to Computers subject –"*Introducción a los Ordenadores*"- undertaken at the Castelldefels Polytechnic School, a good standing center for its high quality teaching, for its wide experience in the subject adaptation to the European credit system requirements, and for being one of the pioneers in applying the cooperative project-based learning in Spain.

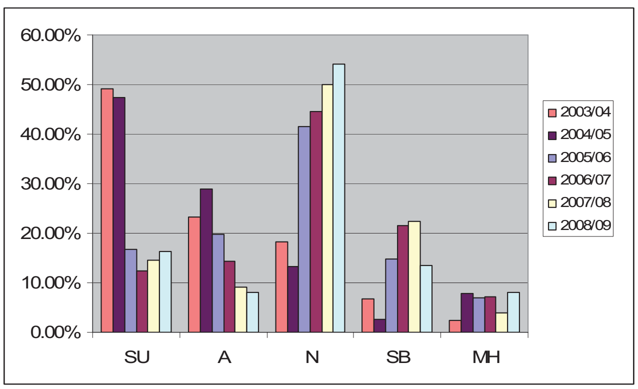

Figure 1. Data trend of the Computer Programming subject grades.

Results of this adaptation are shown in Figure 1. It can be observed failure rates ("SU") drop sharply since 2005/06, while pass rates ("A") decrease at the expense of higher rates ("N", "SB", and "MH"). Therefore, it can be inferred, using this student-centered new methodology, more students pass the subject and with better marks.

According to the promising results obtained in this trial experience over a single subject, last year this approach was extended to a new subject in the second semester, Programming of Multimedia Applications –"*Programación de Aplicaciones Multimedia*"-, thus incorporating a new element to this approach: a multidisciplinary project along a learning thread. Thereby, the project performed during the first semester in the Computer Programming subject is broaden, modified, and completed in the second semester during the Programming of Multimedia Applications subject.

III. MODEL-VIEW-CONTROLLER PROGRAMMING PARADIGM

After considering several organizational schemes, the model-view-controller (MVC) paradigm was considered the most appropriate to implement the steps comprising the proposed learning thread.

MVC was first described in 1979 by Trygve Reenskaug [3] , then working on Smalltalk at Xerox PARC. The original implementation is described in depth in the influential paper "Applications Programming in Smalltalk-80: How to use Model–View–Controller" [5]. There have been several derivatives of MVC. For example, Model View Presenter is used with the .NET Framework [7], and the XForms standard uses a "model-view-controller-connector architecture" [1].

At the heart of MVC, the idea that was the most influential to later frameworks, is what it is called Separated Presentation. The idea behind Separated Presentation is to make a clear division between domain objects that model our perception of the real world, and presentation objects that are the elements we see on the screen. Domain objects should be completely self contained and work without reference to the presentation; they should also be able to support multiple presentations, possibly simultaneously. In MVC, the domain element is referred to as the model. Model objects are completely ignorant of the user interface. The presentation part of MVC is made of the two remaining elements: view and controller. The controller's job is to take the user's input and figure out what to do with it. It is important to highlight that there is not just one view and controller. There is a view-controller pair for each element of the screen, each of the controls and the screen as a whole.

A very common issue for the programmers is code reusing and refactoring. Many times we have to solve a problem similar to another one previously resolved, to improve the interface of a program, to optimize the underlying algorithm, etc. These tasks can be simplified separating the code into parts which can be reused without any modifications. Based on these premises, in order to reuse a code for future software development, the model must be independent. Model classes (or functions and structures) should not access any class from another group. This way we can compile the model in an independent library reusable for similar developments. Furthermore, if the software is developed using C programming language and we change the platform used (from example, from Linux to Windows), it should be possible to recompile the C code with minor modifications. So the model should not include any concrete graphics, sockets or other library calls which are usually very different, even within the same platform, if we use a different environment (think, for example, in graphics with Visual C++ and with Borland C++, both under PC/Windows).

Besides, the controller can (and usually does) access model and view classes by reusing code. View is the more changing element, so we link it to the controller classes. If we change the controller, at least we will have to recompile the graphics interface.

To get all this operating, the main function has to instantiate the model, controller, and view classes. In case a new graphics interface has to be developed, we will work without modifying the previously developed model and controller. It will be enough modifying the creation/instantiation of the graphic interface to include the new developed version. Everything should work without even recompiling the model and the controller.

IV. ITINERARY OF THE LEARNING PROCESS IN THE ALREADY ESTABLISHED THREAD

In order to perform a reusable project, a learning thread shared between several subjects was proposed. In a first implementation, it included two subjects: Computer Programming and Programming of Multimedia Applications. Performing the project should mean meeting both the final goal and the associated objectives. Each subject has its own partial goal (subprojects SP1 and SP2). In Figure 2 it can be observed the final architecture of the proposed project integrating the contribution of both subjects.

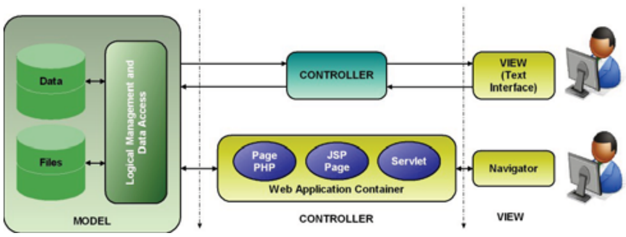

Figure 2. Architecture of the multidisplinary project to be developed in two subjects.

TABLE I. BREAKDOWN IN STAGES OF THE ESTABLISHED ITINERARY

Subject	Contribution to the thread	Result
Computer programming • 1st grade • 1st semester	Solving a complete problem using a high level programming language with a modular structure. Knowing how to specify and design modules and databases. Assembling a simple set of codes in a cooperative way using separate compilation units. Building a collection of function libraries.	SP1: A complete single-user application accessing to the application data following a model-view-controler (MVC) pattern. Text User Interface (TUI).
Programming of Multimedia Applications • 1st grade • 2nd semester	Solving same problem as previously presented with Web technologies. Developing a new graphic interface (view and controller) using HTML, CSS, JavaScript, and PHP programming language. Developing a new model if appropriate, or otherwise accessing to the previously developed model. Building new classes/modules (PHP) for accessing to the database (MySQL) into the model.	SP2: Adding to the application a new way of accessing, through Internet. User interface is a web site with dynamic pages. Controller are codified using a server language (PHP) and accessing to a database (MySQL).

MULTIDISCIPLINARY PROJECT: A TRAIN RIDE MANAGEMENT SYSTEM

As a specific example of a reusable project within the shared learning thread, we proposed last school year in the subjects Computer Programming and Programming of Multimedia Applications, a train ride management system. The project is divided into two different applications sharing same data. The first one, called *Management*, will be used by the travel agents to handle the information about train stations and rides. The second application, *TravelPlanning*, will be used by travel agents to provide the better travel plan to the clients according to their needs with the possibility to choose among the shortest, the fastest, and the cheapest travel. To compute the shortest path, the Dijkstra algorithm will be used.

A. Computer Programming

Students gain the abilities needed to solve a complete problem using a high level programming language with a modular structure, following the model-view-controller paradigm. They build a set of libraries in a cooperative way to perform mixed functions.

As a result, we obtain a complete single-user application (one process only) accessing to the application data by a hierarchical menu-based information retrieval system developed in a text user interface. Application execution is sequential and ruled by the main program controlling the evolution of the system states, particularly, the "dialogues" (input/output operations) which are always synchronous.

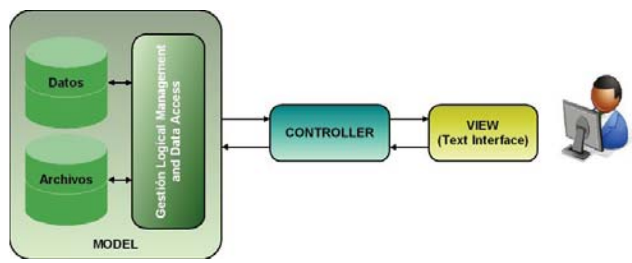

Figure 3. Architecture of the project to be developed in the Computer Programming subject.

MULTIDISCIPLINARY PROJECT RESULTS

In this first subject, the train routes planner problem is analyzed, designed, and implemented in two versions, using both C and C++ programming languages. In terms of the MVC paradigm, both applications use the same model and its view is a console application. In both versions, viewable result is exactly the same (see Figures 4 and 5).

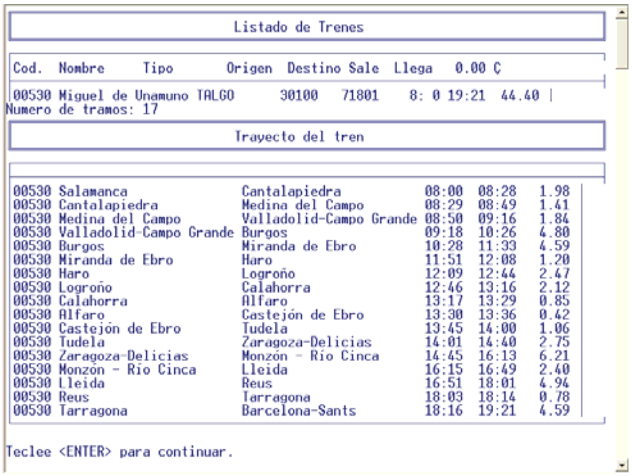

Figure 4. Screen shot of the *Management* application performed in the Computer Programming subject.

Figure 5. Screen shot of the *TravelPlanning* application performed in the Computer Programming subject.

B. *Programming of Multimedia Applications*

In this stage, the web technologies (HTML, CSS, JavaScript, PHP and SQL using MySQL DBMS) join to the learning thread. In this case, view will be a web page in a browser, which provides access from different platforms. Controller will be recoded using PHP and model (business logic) will be also recoded if necessary.

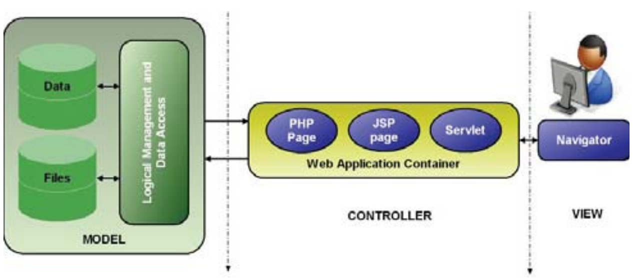

Figure 6. Architecture of the project to be developed in the Programming of Multimedia Applications subject.

As a result, we obtain a multi-user web application providing a user-friendly access from different platforms. This subject will disappear with the new grades, in its stead it will be lectured the subject Technologies of Web Applications ("Tecnologías de Aplicaciones Web"), where the web technologies can be widen.

MULTIDISCIPLINARY PROJECT RESULTS

The students start this subject using the first phase of the developed multidisciplinary project. The analysis and design steps have been previously done, so it is not necessary to prove abilities already evaluated in the Computer Programming subject. Within the MVC paradigm, the tasks to be performed to acquire the abilities covered by this subject are:

- Model: in the first version, data were stored in files. Now, a database will be added using MySQL.
- View: in the previous version, the user interacts with the system through a MS-DOS console. Now, a web site will be design to insert data and view the results obtained using the above-mentioned web technologies.
- Controller: the business logic was already designed and this design is language-independent. Now, the controller will be coded using the PHP language.

Therefore, the local application developed in the Computer Programming subject evolves into a network application with a graphic interface, more user-friendly than the console.

Figure 7. Screen shot of the *Management* application performed in the Programming of Multimedia Applications subject.

Figure 8. Screen shot of the *TravelPlanning* application performed in the Programming of Multimedia Applications subject.

V. ITINERARY OF THE LEARNING PROCESS IN THE THREAD PROPOSED

With the new grades starting, the Telecommunication Engineering degree will disappear while Telematic Grade will be established. Based on the gained experience and on the results obtained using the learning thread previously explained, a new learning thread is proposed with a multidisciplinary project along the four years of the Telematic degree. Hence, to better accomplish the final goal and the associated objectives, a five-step itinerary is proposed. Each step is tied to a subject, which has its own partial goal (subprojects SP1 to SP5). In the Figure 9 it can be observed the final architecture of the proposed project integrating the contribution of all the subjects.

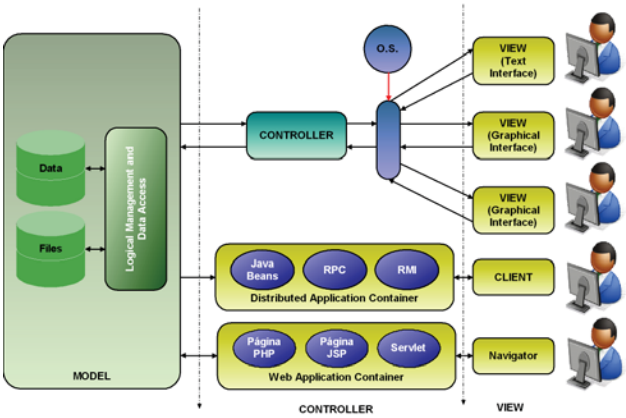

Figure 9. Architecture of the multidisplinary project to be developed along the degree.

TABLE II. BREAKDOWN IN STAGES OF THE ITINERARY PROPOSED

Subject	Contribution to the thread	Result
Computer programming • 1st grade • 1st semester	Solving a complete problem using a high level programming language with a modular structure. Knowing how to specify and design modules and databases. Assembling a simple set of codes in a cooperative way using separate compilation units. Building a collection of function libraries.	SP1: A single user complete application accessing to the application data following a model-view-controler (MVC) pattern. Text User Interface (TUI).
Computer Fundamentals and Operating Systems • 1st grade • 2nd semester	Incorporating concepts concerning to the operating systems to the project like the process planning, the process concurrency, and the communication between processes.	SP2: A complete multiuser application controlled by a dedicated operating system. The O.S. creates the semaphores and launches and controls the process controller and several view processes.
Software Systems Engineering • 2st grade • 2nd semester	Object-oriented programming. Software engineering. Event-oriented programming. Graphic interface.	SP3: Application is recoded using engineering software techniques. Controller is re-design using classes. A graphic interface is designed. *Database* access and management class library.
Architecture for Distributed Applications • 3st grade • 2nd semester	Client-server architectures. Sockets, middleware (RPC, RMI, EJB,…)	SP4: Adding to the application a new way of accessing: the remote access from other computer.
Technologies for Web Applications • 4th grade • 1st semester	Solving same problem as previously presented with Web technologies. Developing a new graphic interface (view and controller) using HTML, CSS, JavaSCript, and PHP programming language. Developing a new model if appropriate, otherwise accessing to the previously developed model. Building new classes/modules (PHP) for accessing to the database (MySQL) into the model.	SP5: Adding to the application a new way of accessing, through Internet. Use interface is a web site with dynamic pages. Controller are codified using a server language (PHP) and access to a database (MySQL).

Next, each subject contribution related to the learning thread will be explained. The contribution of the first and fifth subjects, already involved in the previous learning thread (Computer Programming and Technologies for Web Applications, earlier Programming of Multimedia Applications), are omitted as they were already explained.

A. *Computer Fundamentals and Operating Systems*

In this stage, new concepts over operating systems (O.S.), process planning, and communication among processes are built into the project.

The O.S. process of the application establishes the semaphores needed to control the concurrently access to the model of several clients and manages the communication between the controller and the view processes, applying different planning methods.

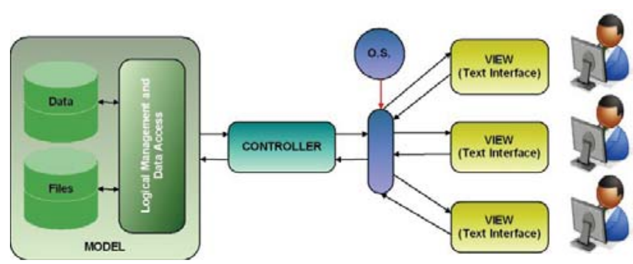

Figure 10. Architecture of the project to be developed in the Computer Fundamentals and Operating Systems subject.

As a result of the contribution of this stage, we obtain a complete multi-user and multi-process application managed by techniques used in real operating systems. In this stage communications among processes of the same computer are manage, which provides a background to the client-server architecture and the communications among process of different computers that will be study in next stages of the thread.

B. *Software Systems Engineering*

In this stage, methods from software engineering and application implementation are incorporated to the thread. The starting point is the analysis performed in the Computer Programming subject, then, the design of the required classes is performed. The model is encapsulated in a class library. The visual interface is designed following the event-oriented programming paradigm. Controller is also developed with classes.

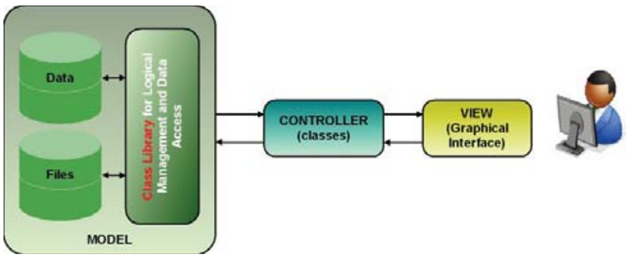

Figure 11. Architecture of the project to be developed in the Software Systems Engineering subject.

As a result of the contribution of this stage, we obtain a system completely implemented using classes, maintaining the model-view-controller scheme.

Including the result obtained in the Computer Fundamentals and Operating Systems subject, a system accessed from textual or graphic interfaces, or with the controller developed using structural or object-based programming language can be obtained. Furthermore, the function or the class library can be used, depending on the preferences or on the application to be developed.

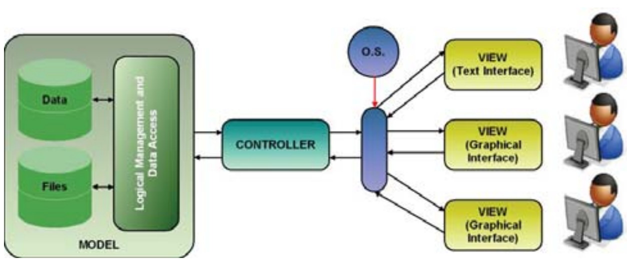

Figure 12. Architecture of the project to be developed in the Software Systems Engineering subject including the results obtained in the Computer Fundamentals and Operating Systems subject.

C. *Architecture for Distributed Applications*

In this stage, concepts related to remote communication among processes in distributed applications –sockets, middleware (PRC, RMI, EJB,…) are added, thus expanding the knowledge about communication among processes within the same computer provided in the Computer Fundamentals and Operating Systems subject.

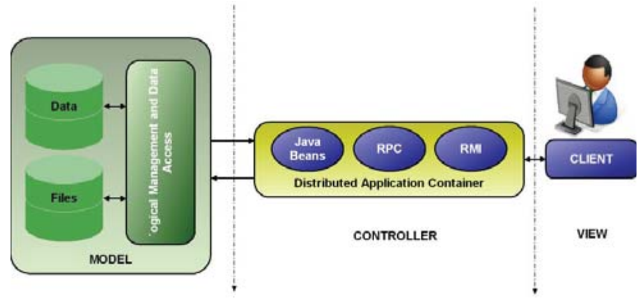

Figure 13. Architecture of the project to be developed in the Architecture for Distributed Applications subject.

As a result, an application is obtained keeping the model while controller is recoded, using specific technologies for distributed processing in different machines. View can be found in the same computer or in other.

VI. MOODLE: TOOL FOR LEARNING SUPPORTING

Some tools implemented as modules for the Moodle platform have been specifically designed to exploit the full potential of the PBL approach. A module called e-Liza is used for both a self-evaluation and a competitive evaluation of the gained knowledge. In e-Liza the questions are not only proposed by the teacher but also by the students. Of course, the last ones are supervised by the teacher accepting them or not, and assigning the difficulty level. Statistics of the individual or grouping play are shown to the students in order to keep them informed of their progress.

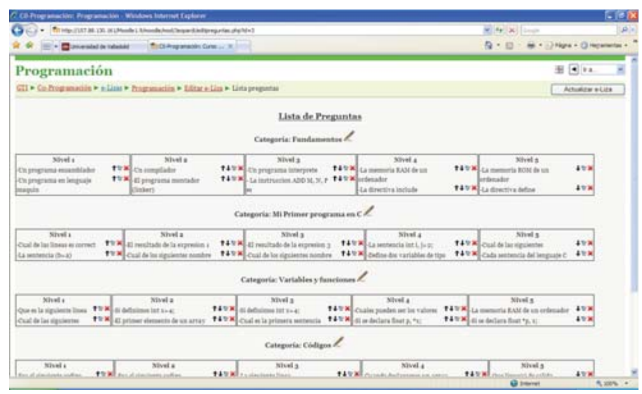

Figure 14. Screen shot of the module e-Liza, the section for entering the questions.

Another tool to perform questionnaires is used both for creating evaluation templates used in the peer-reviewing and for conducting surveys of the curriculum development. Students can also use other modules specially designed for each of the subjects, for example programming validators, also integrated in the Moodle platform. All these tools are very useful not only for the students making the learning process easier, but also for the teachers specially helping them in the classroom management, because this new approach adds more workload than the classical one, at least in their beginnings.

VII. Conclusions

In this paper a learning thread shared by several subjects of the Telecommunication Engineering degree related to application programming has been proposed. The goal is to place the student in a realistic scenario, facing real-world issues and following a pathway leading to the development of a global project throughout several years. Results obtained in the trials previously conducted are encouraging. Students get higher involved with the subjects and especially faster than without using this scheme. These facts provoke the students to get better marks, also decreasing the number of dropped out students.

As it has been explained, future work will consist of applying this methodology to a total of five subjects placed in consecutive semesters, coinciding with the new Telecommunication Engineering degrees beginning in the University of Valladolid.

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Session 07C Area 4: Rethinking Pedagogy in Engineering Education - Project based learning and research

A context for programming learning based on research communities
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Retaining electronic engineering students by project- and team-work from the first semester.
Friesel, Anna
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The Use of Role Playing in Engineering Curricula: a Case Study in Human-Automation Systems
Amante-García, Beatriz; Ponsa, Pere; Vilanova, Ramon
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A Learning Approach Based on Robotics in Computer Science and Computer Engineering
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A context for programming learning based on research communities

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Abstract— **This paper describes a research work that seeks to develop a pedagogical strategy to assist in programming learning, inspired by Mathew Lipman's strategy – conceived to help students maximize their learning through the conscious assessment of their self-efficacy level while they develop a programming study behaviour. We present the results of the preliminary tests on the formalization of the research methodology and the changes implied on the strategy to be tested.**

Programming learning; Research communities; Literary skills; Self-efficacy

I. INTRODUCTION

There seems to be a consensus among teachers and researchers that regards programming learning as a non-trivial activity, as it introduces a new series of cognitive requisites in students' routines, besides the technical requisites. This creates in students the need to change and adapt their way of thinking and manage time in college life to a different reality than the one lived through primary school and high-school. A change in a very short time frame. Among these requisites we may highlight:

1. Problems solving is above all a competence that involves cognitive processes - such as creativity and rationality - from a set of mental meta-abilities (abstraction, inference, deduction, etc), meta-abilities that sometimes come unnoticed and are supported on the exercise developed through their basic literacy skills (like reading and interpreting the description of a problem). Besides, in order that the student may start the aforementioned cognitive processes so that he can use his mental skills to build a solution, he needs to learn how to contextualize the acquired knowledge.
2. The whole understanding of a programming paradigm's requisites is not a trivial activity and implies an intrinsic natural difficulty level [1, 2]. However, the major difficulty in programming learning lies on the ability to abstract the acquired knowledge to solve problems. Abstraction and problem resolution abilities can only be obtained through individual effort and continuous practice. Having well-developed literacy abilities will be of extreme importance to ground the cognitive processes and to support the learning being created.
3. Although computer science is part of the students' daily life from an early age on, the transparency level intrinsic to the relationship user-computer leads them into a false sense of intelligent autonomy of informatics systems. Sometimes it is difficult to make them understand the difference between the notion of systems transparency and their responsibility in the relationship programmer-computer.

The abilities of abstraction and problem solving are underdeveloped among university newcomers from high-school. The lack of excellence in their development is further stressed by the superficiality of their literary skills [3, 4], crucial to a productive academic life and to develop the technical abilities proposed in the syllabi of university courses.

The major problem concerning programming teaching does not lie only on the difficulty students have to abstract and solve problems. There is still the difficulty in finding a way that motivates students to get involved in the course in spite of their handicaps and to not give up trying to overcome the natural barriers inherent to this learning [5]. It is vital to make them realise that the obstacles are surmountable and that the demanded skills may be developed and improved, encouraging them to develop and strengthen a set of essential academic competences so that they may better improve in their studies and in their future professional life.

II. TEACHING TO THINK

Access to education is an evident concern of today's society and of the global economy, with a strong commitment from governments of rich and developing countries in initiatives to improve and offer better conditions for learning in the different stages of the educational system: the enlargement of vacancies in the educational system, the evaluation of the quality of teaching, developing policies of social and digital inclusion, investment in the renovation of classrooms and laboratories with computing equipment and programmes to improve the qualification of teaching staff.

Nevertheless, those reforms have not yet been able to produce a system that can develop towards the "teaching to think" concept. There is nowadays a great number of students, from elementary to high school, who do not develop well enough the different abilities and competences necessary to evolve in a more productive way throughout university years, as shown in the results of the International Programmes of Teaching Evaluation [6].

The growing number of students in the university system has burdened the traditional academic model. In a short timeframe there was a growing demand that made the academia need to change their way of work and educational model, without a previous preparation to adequately respond to that demand.

Facing the urgency in finding ways to manage this situation, the academia often chooses processes that privilege administrative issues (classes format, resources allocation), which is not always the best solution under a didactic point of view. Although there is a need for a renovation in the academic life to better suit the new reality, it is a process that is under development and where the administrative reforms end up influencing the evolution of didactic processes.

A. Critical and Creative Thinknig

Matthew Lipman is an educational theorist who has called the attention from the North-American Academic Community in the seventies with his proposal of Teaching Philosophy to children, we called "Pedagogy of Judgment" (Philosophy for Children – P4C)[7]. It suggests to "teach to think" using the philosophical speeches, proposing teachers to readopt the Socratic teaching as a didactic approach.

His goal is to start in infancy a long term process of development of critical and creative thinking, joining literacy and language acquisition which will last throughout all the formal educational process that the child will live. In that proposal, at the same time the child begins to develop literacy skills, he/she also starts the continuous development of his/her abilities to think, going from the stimulus to the capacity of judging fairly.

To Lipman, issuing a judgment is a behavior that sets the basis for the qualitative development of the most relevant cognitive abilities for educational goals (research, reasoning, information organization and translation), thus making an elementary unit of thought. Judging is the basic cognitive unit for the development of critical and creative thinking, and it is influenced both by criteria (its rational element) and by individual values – the emotional element of its composition.

His proposal defines practical actions which converge with the thinking of John Dewey, Lev Vygotsky and Jerome Bruner, aiming at changing the wrong concept that childhood innocence impedes the child from learning to use reason as a learning tool. His work shows that the lack of motivation to learn must be understood more as a result of the evolution of non-reflective practice of the traditional educational model, rather than the "innate" lack of curiosity from the student [7].

This pedagogical strategy is implemented from a Lipman's redefinition of the concept of learning communities which he called "community of inquiry". Lipman's proposal is an appeal to teachers so that they focus their practices in guiding students in a search for knowledge: motivating them to learn how to consciously identify what they already know and what they need to know not only how to solve a problem but also to be able to think on and assess the quality of a solution.

B. Teaching to think in programming

There is an intense effort from researchers and teachers in trying to understand the reasons that make programming learning be seen as an obstacle for a growing number of students [8, 9].

In fact, the major problem is not language or the programming paradigm, but the difficulty to develop competences that make the student able to contextualize his/her knowledge in order to solve problems. It is important to make the student realise that programming is, above all, a conscious exercise of the mental abilities that are developed and offered in an appropriate context to support the development of several cognitive abilities [10,11].

Some researchers aim at a restructure of curricula [12], but that can only be implemented through the change in the way activities are proposed and to evaluate the progress of the student's learning [13, 14]. There are advances that can be obtained for instance with the regular practice of activities related with research and reflexion for problem solving, abstraction, modelling and the evaluation of the quality of algorithmic solutions [15, 16].

It would then be possible to understand programming learning as a situation that encompasses nuances similar to the context of language acquisition by children. Up to a certain extent, learning how to program requires a change in the way of thinking, according to the paradigm's precepts, just as when one learns a new language.

The relationship of mutual influence between language and thought is evident [17], and resembles to the relationship between language and the programming paradigm. That is why it is relevant to get close to Lipman's approach to programming learning.

Although the pure philosophical speech is not *per se* a natural approach to teaching practice in programming, the methodical and reflective thought that comes from the dialogue inspired in Science Philosophy is rather useful.

Literary skills may thus be reinforced together with programming teaching, as they will assist in the learning of the several stages of abstraction and modelling of an algorithmic solution and in the software development process. Furthermore, as one develops mental abilities, that usually influences the qualitative improvement of the several literary skills (reading, interpreting, summarizing, criticizing, etc), and vice-versa [7].

Thus, rather than just being able to define a methodology of teaching-learning for programming, it would be interesting to be able to establish a set of strategies that show students that solving programming problems is an activity that they are fully capable of accomplishing. It is important to value contexts and establish a dynamics in class that may motivate students to teamwork, giving evidence and making them aware that individual difficulties are surmountable so that they get ready to "learn to think" [18, 19]. This should lead to a higher student commitment to their learning, including behavioral changes that may improve their performance throughout the course.

III. MOTIVATION AND LEARNING

Motivation has a great impact on the individual's cognitive development and is a determinant factor for the individual success in a learning process. It is also among the most fascinating features of the human psyche, having one of its main research origins in Maslow's Motivation Hierarchy [20]. Understanding motivation to learn requires a deep analysis of the socio-cognitive components associated with personality (identification with the institution, Degree, career, accessibility to teaching and the analysis of school success) and the quality of relationships in coexistence environments (social identification and learning approaches) [21].

Along evolution in the formal learning process, from primary school, the student faces several tasks, contexts and learning methodologies. From those experiences the student develops his/her study behavior, finding a learning strategy and the method and activities that best fit his personality, his beliefs and values. Yet, it is not possible to underestimate the impact of the experienced learning methodology, as it influences greatly the type, quantity and quality of the abilities and competences that will be developed. This ends up merging within the study behavior of students of a whole generation.

Motivation presents itself as a domain of crucial impact on learning tools and learning [22], and several theories and instruments have already been described to classify measure, create and maintain students' motivation, especially among children and teenagers [23].

With the advance of research in Distance Education (DE), tools inspired in the John Keller's Motivation Model ARCS (Attention, Relevance, Confidence and Satisfaction) [24], have been widely used in course modelling and e-learning environments.

Formal tools to evaluate motivation measures (comfort, self-efficacy, satisfaction) such as the Inventory of Attitudes and Study Behaviours (IABS/IACHE) [25], are important and seek to assess features related with the students' learning strategies. The IASB is an independent, generic behavioral test with which it is possible to evaluate:

- If a didactic strategy may or may not satisfy a set of learning requisites in a given course;
- To point the existence of changes of attitude from the student regarding his/her academic performance
- To establish statistical parameters of a population, identifying the proportions of cognitive, motivational and behavioral dimensions.

The IACHE encompasses cognitive, motivational and behavioral dimensions, distributed in five sub-scales [25]:

- Comprehensive focus, using reflection and a deep content analysis, which implies for the student a greater effort and time in learning;
- Reproduce focus, a tendency to spend only a minimum effort on a superficial learning, based on memorization and contents reproduction;
- Involvement, or motivation, because this related essentially with requirements of intrinsic motivation
- Organization, it analyzes the indications of establishment some organization level on activities of study;
- Competence personal perception.

Other tools focus on more specific features, such as the case of the Course Interest Survey – CIS and the Instructional Materials Motivation Survey-IMMS) [26], two motivation evaluation tools, created in the framework of the ARCS model. CIS and IMMS may show the levels of attention, relevance, trust and satisfaction among students regarding a given course (pedagogical approach, classes rhythm, teaching practice, proposed activities) and the didactic materials used (textbook, handouts, worksheets).

The analysis of the study behavior through tools like IACHE may provide crucial information on the students' behavior, both individually and as a group, allowing to guide and/or to evaluate the selection of activities, methodologies approach and pedagogical practices for students with specific characteristics.

Although tools like IACHE and CIS have been proposed to measure motivation, there is the need to evaluate the level of acceptation and rejection of students to do the activities [27], as well to establish a motivation measure more closely associated with the aptitude of students to learn to program, which would also allow it to be measured with total independence from the other motivational models observed.

That motivation measure is self-efficacy [28], evaluated from scales directed associated with a self-analysis of the ability or inability of a student to perform a specific task. Self-efficacy scales for programming are a formal tool that may be independently and regularly used [29], and which can aid to maintain the student alert regarding the quality of his/her learning, offering another perspective of the assessment of his/her capacity, different from essays and exams' grades.Units

IV. PROPOSED PEDAGOGICAL STRATEGY

This pedagogical strategy aims at defining a theoretical framework that encompasses a set of recommendations regarding contexts and didactic activities, computational tools and motivational strategies that may assist the teacher in the definition of learning contexts for programming courses, as shown in figure 1. The goal is to try to identify the conditions that may make programming learning more stimulating, minimizing drop-out intentions and making the student learn more and better.

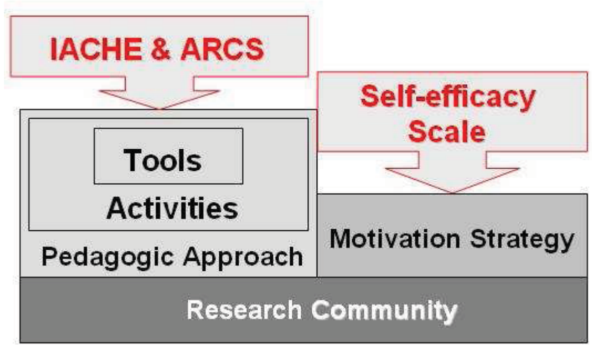

Figure 1. Theoretical scheme of the strategy.

This is a proposal developed under the perspective of learning communities, inspired by a metaphor of Mathew Lipmanp's research communities [7], considered to be a rather relevant abstraction for proposals involving the development of critical thinking [30] and literary skills, and also as a strategy to improve the capacity of solving programming problems among university students [31].

Learning communities are already a renowned perspective, both educational and technological, that allows the creation of contexts in which it is possible to reinforce learning through the association between collaboration activities and knowledge production [32]. Besides, that perspective favours the practice of several literary and mental abilities that will be necessary to students throughout their academic, social and professional lives.

The dynamics of Lipman's Research Communities for programming teaching defines a didactic approach that would allow the teacher to work in several different contexts: Problem Based Learning (PBL) [33], Just-in-Time Teaching (JiTT) [34], hands-on projects [35], games [36] and programming competitions [37] for example.

This is the first foundation of that proposal, i.e., the teacher should decide his/her didactic approach, being able to choose any of the suggested contexts to determine: how and which didactic activities will be developed, and which support tools he/she will use in the course. We suggest these contexts as they have appeared in the literature as well succeeded examples in programming learning.

When choosing the context the teacher should take into account some facts as class size, which can make certain contexts harder than others.

After choosing the context, the dynamics of Research Communities will be developed together with didactic activities planned to strengthen the student's involvement with the process of knowledge acquisition and development of competences to solve problems, through teamwork and the motivation to practice their literary skills in several ways:

- Research activities – which increase the research of content for the solution of problems, e.g.: research questions, evaluation simulations, exercises of discursive evaluation of the algorithmic quality of solutions, practical and/or programming challenges with different complexities, either individual or in group;
- Collaborative/cooperative knowledge production – adoption of methodologies and collaboration tools in reinforcement activities, peer review, motivation for the production of portfolios, webquests, seminars and participation in competitions;
- Distribution of work and tutoring – stimulating the use and recognition of voluntary tutoring between student-student and student-tutor;
- Continuous assessment – regular feedback tasks between teacher, tutors and students on the course evolution.

Programming learning demands the choice of technological tools that can support programming learning and collaborative work. We see as an advantage the use of algorithmic simulation tools and learning support programs adequate to the studied language and paradigm (RoboCod, Alice, BlueJ, o JavaTool e and SICAS, for instance). Competition and Test Platforms like TopCoder, Mooshak and Online-Judge are also welcome.

To stimulate extra-curricular activities and to support the monitoring and continuous assessment tasks, it is advisable that there is the support of a learning management support, such as the Moodle, Blackboard or AulaNet.

The second founding concerns the need to use a supporting strategy for the maintenance of good motivation levels for the students' learning during the community work. Regarding this, it is important that the teacher may be able to identify specific moments to intervene, advise and settle the students' frustrations concerning their performance [38]. The availability and sensitivity of the teacher are crucial to evaluate the students' progress and commitment, as well as to assist in the maintenance of their motivation levels.

Motivational measures such as the comfort level, self-efficacy, confidence, usefulness and satisfaction with the proposed activities should be checked regularly in order to be able to guide the work rhythm and to adequately direct the teacher's efforts for intervention actions, whether in the daily motivation or in the prevention of behaviors that may lead to students dropping out.

A. Methodology of Pedagogic Strategy Evaluation

The proposed strategy will use measurements of the usefulness of the proposed tasks along the course as well as some formal psychological tools to evaluate several cognitive aspects related with motivation: a survey on the features of study behaviour through the IACHE tool, an evaluation of the levels of satisfaction with formal aspects of the course development through ARCS, and a measurement of the students' levels of self-efficacy in relation with language and the studied paradigm.

The results of the IACHE test, as they are not *a priori* related to any course or degree, will be used to assess if the use of a certain learning approach has produced any changes in the study behaviour of a given population.

The motivational levels measured by the ARCS model will provide the evaluation of the evolution of the course (contexts, teaching assessment and used resources). For each proposed task there will be a survey to check those measurements at the end of the course.

Finally, a regular application of a self-efficacy scale in programming will be used [39], making the students aware of their competence level to carry out tasks with the studied language and paradigm. That awareness can better guide their studying efforts and stimulate the evolution of the necessary competences for programming learning, identifying the ones which are at an average or rudimentary level.

The evaluation scheme influences the application of CIS test in the middle of the course, and surveys will be made alongside the proposed tasks. Both the IACHE and the self-efficacy scale will be applied in the pre-tests and post-tests scheme, where the IACHE will take place at the beginning and end of the course. The self-efficacy scale will be applied in the middle and end of the course, preferably before the tests of knowledge evaluation.

V. AN EXPERIMENT WITH STUDENTS OF DESIGN AND MULTIMEDIA

Most programming courses of the Department of Infomatics Engineering usually present a high number of enrolled students - between 200 and 300- and a high level of heterogeneity among students in one course, from the several degrees offered in the Faculty of Sciences and Technology of the University of Coimbra (FCTUC), like Informatics Engineering, Industrial Engineering, and Design and Multimedia. The teaching model encompasses:

- Theoretical classes (2 hours): all students enrolled attend a lecture by a professor in a classroom;
- Practical classes (2 hours): students enrolled are divided into classes of up to 30 students to carry out practical lab activities with the same professor of the theoretical class or some other teacher, and:
- Lab practical classes (2 hours): support classes, remedial work or clarification of doubts, non mandatory, given by course tutors.

Applying an experimental strategy in this scenario would be risky and very time consuming. Any change in the pedagogical dynamics and work methodology within this kind of courses would not only imply a more laborious routine for the teacher, but would also raise the chances of failure of the proposed strategy.

Thus we chose to start with a small course, where management and changes control is much easier. The proposed strategy has started being developed in two stages, with students of the Programming course from the Masters Degree in Design and Multimedia (MDM): the first stage carried out from September to December 2008 and the second, still ongoing, started in September 2009. The aim of this course is to offer students a minimum programming knowledge that may allow them to participate in other courses of the degree that require previous programming knowledge.

The course's syllabus was developed according to the dynamics of the Research Communities, and the didactic approach was conducted to provide a practical learning. In the experiments carried out the following activities are used: individual seminars on artistic projects and applications developed with the supporting language, practical group work assignments, discursive evaluation of algorithmic quality from the peer code analysis, producing an artistic portfolio in programming , and continuous assessment.

The exercises and projects proposed involve a need for research, especially the review of algebra and mathematical knowledge, with monitoring from the teacher and motivation for regular qualitative assessment of the assignments accomplished in teamwork.

Bearing in mind the artistic background of the students participating in the experiment, we chose to use the programming language and IDE Processing programming language as a development tool. It was created at MIT by and for graphic designers [40], a tool that expands and facilitates the capacities to develop artistic works with JAVA language.

In the adopted strategy there is no distinction between theoretical, practical or lab practical classes. All classes are spaces for knowledge construction and practical experimentation, making up a total of 6 weekly hours of work. The course holds a class at the DEI's Moodle, where materials are available and some tasks are performed.

The size of MDM's classes made an almost one-to-one student monitoring possible. It has also maximised the opportunity for the teacher to know crucial characteristics of the students, changing the class dynamics to an eminently research approach during the practice of problem solving in groups.

A. First Stage

The first stage group included 11 students, mostly recent graduates from the BSc degrees in the areas of design (Multimedia, Industrial or Communication) and architecture. We chose to use the context of visual hands-on projects of growing complexity, as it would facilitate the students' involvement and interest in the creation of varied practical work.

In this stage the original idea was to verify the coherence of the desired approximation to Lipman's approach, for which a continuous assessment system was used, through the fulfillment of several proposed tasks. Moreover, the evaluation included to check: students' satisfaction with their own performance, tasks, materials and classes rhythm through biweekly reflection about the course evolution in the Moodle platform.

Among the positive aspects point out in the records we can highlight the following: research activities and code analysis, team work and class dynamics. Those activities are considered essential for the approach proposed by the Research Communities, enriching it as an interesting approach for programming teaching. Surprisingly, the peer evaluation tasks and the continuous assessment, as well as the artistic contexts proposed in group assignments, are positively evaluated although with a frequency way below expected.

Amid the most scored aspects in the evaluation of negative points, we highlight: the mathematical examples used during the arrays content, the first challenge of the course involving animation programming of a circumference mathematical model and the lack of individual commitment from students. Among the least scored negative points we underline: the delay in the teacher's feedback, classes' schedule, features of the Processing tool and OOP.

By the end of the course students answered an 8 questions interview related with the perspectives of the ARCS model, in which they presented their evaluation on the course, as well as aspects related with their school trajectory.

The most interesting answers were:

1. What do you consider to stimulate your interest in a course: the syllabus (25%), practical tasks (25%), your individual interest on the subject (25%), when you feel curious on the subject (18%). Only 7% consider the usefulness of the course as important;
2. Do you consider as positive the experience in courses where: there was a clear practical feature (25%), you liked the contents (21%), you felt inspired by the teacher (17%), you felt that the contents were interesting/useful (14%);
3. Do you consider as negative the experience in courses where: teachers were not motivated, with inconvenient, derogatory and/or authoritative attitudes (25%), the contents were not interesting to you (25%), there was a theoretical and expository prevalence (17%) you considered them useless (10%). Only 3% reported a failure in their own studying time management regarding studying.;
4. How do you manage your motivation to learn: in uninteresting activities you do not dedicate more than the minimum required (32%), you believe it is natural to feel unmotivated in certain periods (26%), you try to finish an uninteresting task as soon as possible (21%). Only 3% considered the options of: studying in advance to prevent accumulation of study material or to ask for help to study;
5. What grabs your attention: the usefulness of the task (19%), the teacher-student relationship (19%), the practical characteristics of the course (18%), the teacher's availability (16%), didactics (16%), your curiosity (7%);
6. You feel confident in a course when: you know something on the subject (40%), you trust on the teacher's knowledge (28%), you are interested and confident in the usefulness of the course's subject (12%), you trust the evaluation system used by the teacher (8%);
7. For a task to be interesting, it depends on: adopted context (30%), the clear relationship between theory and practice (26%), empathy with the teacher (26%). Nevertheless, 18% believe that some courses are naturally uninteresting, no matter what they propose;
8. The position of the Programming course in case a ranking concerning the interest on the course was organized: first place (25%), second place (33%), third and fourth place (18%) and fifth place (10%);

The result of the interviews corroborates with the aspects identified in the bi-weekly reflections analysis, with some pleasant surprises:

- Of the five courses attended by students in that semester, Programming and Internet Technologies were the ones that caused more negative expectations due to the frustrating experiences many say to have gone through during their BSc;
- The reports of good experiences with courses denoted the importance of the relationship between didactics and the teacher's posture. They have mentioned as positive experiences in courses where they did not feel attracted by the contents, while they felt inspired by the teacher;
- They have considered Programming a pleasant surprise among the courses they had attended, highlighting the way courses were conducted, the tool which was used and the evaluation process;

Only one student didn't manage to pass the course and the teacher was pleased not only with the results obtained but also with the dynamics of the strategy, and although he recognizes that there is an increase in work, he believes that the way to work is more prolific.

This experience was the first approximation accomplished for the definition of the strategy here described, and it is particularly important to clarify under which foundations it should evolve and which adjustments should be made. Both the feedback and the constant monitoring by the teacher have shown to be extremely important, as they have allowed a better evaluation of the quality and acceptability of the implemented activities.

It has also made possible to carry out on time actions that were adequate for the classes rhythm and the proposed tasks, to address issues of commitment and dispersion, and especially to be able to gain back students with major tendencies to drop out the course.

It also made clear the need to associate a motivation measure, self-efficacy –specifically connected with the language and the programming paradigm used, to support the process of keeping the students committed during the course. This also establishes a change in the evaluation of the experiment results, adopting formal instruments and parameters to evaluate the several components.

B. *Second stage*

There are 12 students in this group, one of them from stage one. Similar to the previous class, most students are recent graduates in the area of arts and design, and only two are student workers.

In this stage we analyse JiTT's potential, as it makes available a set of tasks that are tightly connected with the goals proposed by the Research Communities. On the second stage experimentation we choose to use once again the context of hands-on projects with the creation of a task inspired in JiTT challenges [41]. Although JiTT offers better opportunities for the development of research activities to a programming course [38], we bet on the positive context of hands-on projects received by first stage students.

The context based on hands-on projects and the tasks list accomplished in the first stage have been kept. One of the changes that were incorporated is a change in the organization and alignment of the syllabus' contents and in the evaluation method. There has been an effort so that the introduction of Object Oriented Programming (OOP) concepts is made earlier. Three new tasks have been introduced: individual programming challenges, mini-tests simulation and mini-tests.

Inspired in the JiTT proposal, small programming challenges have been planned in specific points of the course's syllabus, as a way to stimulate individual work, especially outside the classroom. These challenges include a self-evaluation component concerning the merit of the accomplished programming, making the student used to critical assessment and to the exercise of technical competences in software development.

The mini-test simulation is the only non-scored task and it was prepared so that the student may live the mini-test experience in less stressful conditions. The results are corrected and given back to students in a way they may understand their comprehension level of the course. Bad results will be presented in a way to motivate study outside the classroom. The inclusion of mini-tests does not imply a change in the rhythm or in the approach of the adopted didactics, and it is another opportunity to evaluate individually the level reached by students.

The evaluation methods included in the strategy have been are being put into practice in this second stage. In September we applied the IACHE pre-test, in October the Processing self-efficacy scale pre-test, due to academic events, the CIS test and surveys were postponed to November. The results of the pre-tests performed are presented and commented as follows:

a) *IACHE results*

The IACHE survey is divided into three parts, from which only the first one was considered for the analysis. It includes 44 statements. Groups of questions analyse each of the five cognitive dimensions whose answers vary in intensity from 1 (totally disagree) to 6 (totally agree). The score of each cognitive dimension is obtained by the sum of the answers to the questions for that dimension. The reference values and the average point for the comprehensive and organization focus are given by (1) and all other dimensions given by (2).

$$10 < \overline{X} < 60,\ with\ x_m = 35 \qquad (1)$$

$$8 < \overline{X} < 48,\ with\ x_m = 28 \qquad (2)$$

Figure 2. Summary of the descriptive statistic indicators of the IACHE pre-test

		comprehen-sive	reproduce	personal perception	involvement	organizing
N	Valid	12	12	12	12	12
	Missing	0	0	0	0	0
Mean		42,58	29,92	21,50	36,58	35,00
Median		42,50	29,50	23,00	36,00	33,50
Std. Deviation		4,078	4,999	4,462	4,621	6,495
Variance		16,629	24,992	19,909	21,356	42,182
Minimum		35	24	13	28	23
Maximum		49	39	30	44	47

At this point of the research the average values observed in the analysed cognitive dimensions, figure 2, show a rather high involvement level of students, who demonstrate a great predisposition for the accomplishment of the course's tasks. Surprisingly, the average of the comprehensive level was higher than the reproductive level, which can be a reflex of the organization sense shown by students. The low level of personal perception is a good indicator, but the great discrepancy between the maximum and minimum scores of the sample for that specific dimension warns the teacher on the aspects that involve self-efficacy for students who present a very high average value among this population.

There was another analysis carried out, assembling the groups of answers in the dimensions comprehensive focus, reproductive focus, motivation and organization in three intensity levels: low (answers 1 and 2), average (answers 3 and 4) and high (answers 5 and 6). That relationship was used to analyse all dimensions except the personal perception. For this dimension the analysis is carried out in the opposite way: low (answers 5 and 6) and high (answers 1 and 2).

The analysis by answer level in each dimension presented in table 1 endorses the analysis of the average value, i.e, this is an optimistic result in the sense that shows a predisposition of the group for learning, just 3% below the sample of the low level. Success expectations may be slightly larger than the apprehension of the course's contents. Although students do not show a very high sense of organization, there is evidence that many of them seek to develop study strategies directed to comprehension at a deep level. The low percentage shown by the low level of the comprehensive focus is rather significant.

Moreover, the fact that this population shows a high sense of capacities is positive, as students with low self-efficacy expectations tens to invest a lower effort in studying activities. Only 9% of the population is at the higher level of personal perception.

The most significant efforts of the proposal should be orientated towards the recovery of students who present more answers at the low level, and the improvement of those at the intermediate level.

TABLE I. IACHE DIMENSIONS INTENSITY LEVELS ANALISE

IACHE Dimension	Intensity Levels (%)		
	low	*average*	*high*
comprehensive	4	52	44
reproductive	20	47	34
personal perception	56	35	9
involvement	3	42	55
organization	23	59	18

The comparative analysis of scores and more specifically of the dimensions intensity level will only be possible after the conclusion of the post-test, at the end of the course.

b) Self-efficacy Scale in Processing

The scale used, translated and adapted from a scale for JAVA [42], includes 32 statements related with tasks concerning the tool, paradigm and problems solution, answered according to the intensity of the level of confidence: 1 is for totally unconfident and 7 for totally confident. The scale score is given by the sum of the answers.

$$32 < \overline{X} < 224, with\ x_m = 128 \quad (3)$$

The analysis of self-efficacy follows the same process adopted by the IACHE test, where the reference value and the average point for this population is presented in (3). The data of the descriptive statistics are presented, according to figure 3.

Score no teste

N	Valid	12
	Missing	0
Mean		114,00
Median		95,50
Std. Deviation		34,743
Variance		1207,091
Minimum		89
Maximum		192
Percentiles	25	93,25
	50	95,50
	75	133,25

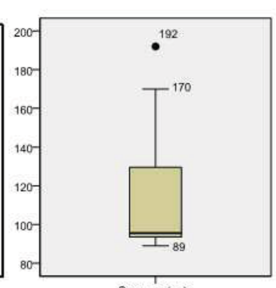

Figure 3. Results of the self-efficacy scale in processsing

The descriptive analysis of the average and the BoxPlot chart shows that there is a large number of individuals whose sense of self-efficacy is very low, since 50% of the population is concentrated on a small amplitude interval between the x_{min} (89) and the median (95,5). The third quarter is a value close to the expected average (128) and thus approximately 75% of the population presents a lower than or equal score to that reference value.

In spite of that statistics result, a more clear conclusion for the studying orientation goals is obtained from the analysis of the intensity level. This analysis reveals a less negative situation, since 63% of the population is concentrated on the average level of self-efficacy (answers 3, 4 and 5), while only 25% are at the low level (answers 1 and 2). Hence, we assume that only one quarter of the sample students consider themselves incapable of accomplishing minimum tasks with the tool, denoting a level of insecurity that makes is suspect that a bad future performance in the mini-tests may actually discourage the student up to the point of no longer doing any effort in the course.

Since self-efficacy is a type of confidence measure that only gives significant modification results when it is at the low level, the teacher's attention should be reinforced towards recovery of students with answers in the low level. Students in the average level may receive the results as an orientation on where to invest their studying efforts, encouraging a more positive expectation of their performance in mini-tests.

It is important to notice and check if the 12% of students who are at the upper level are not too optimistic with the level of their knowledge. In any case, one should not mistake the self-efficacy result with the enthusiasm to learn, checking if, in spite of the positive result, the student is not showing a low commitment with the tasks of the course. All in all, the teacher should adopt intervention measures for guidance and motivation of studying efforts, frustration management and commitment.

As happens with IACHE test, the comparative analysis of scores and more specifically of the dimensions intensity level will only be possible after the conclusion of the post-test, at the end of the course.

CONCLUSION

The general evaluation of the first experiment was considered positive either by students as well as by the course teacher, although there wasn't the full support of all formal cognitive evaluation instruments currently proposed by the strategy. Its accomplishment was particularly important to guide the necessary changes and to plan the second test stage experimentation. It has shown the need to use formal evaluation tools and not only interviews, to validate the strategy's results.

Part of the instruments and premises proposed by the described strategy are also being used to carry out voluntary work, offering programming support to all students of the Faculty of Sciences and Technology of the University of Coimbra (FCTUC), through the Computer Programming Supporting Class. This initiative was backed up by the Faculty's Supporting Office for Portuguese-Speaking Foreign Students, originally aimed at assisting students from Portuguese-speaking African Countries (PALOPs) to strengthen and develop their minimum competences in problem solving and programming. Having first taken place between February and June 2009, the goal is that these students may have better results in the programming courses of FCTUC. This initiative has currently broadened the access so that all FCTUC students interested in this kind of support may be included.

The changes proposed by the strategy also seek to sensitize faculty members and administrative staff of DEI and FCTUC, showing that there are changes which can be implemented in the organization of programming courses, with positive expectations for the quality of learning and more efficacy in the allocation of physical and human resources. In order to pass from reflection to action, it is important that the results of the proposed changes can be formally documented in a set of measures that have been previously tested in contexts as close as possible to the current reality.

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Retaining electronic engineering students by project- and team-work from the first semester

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Abstract— **This paper describes the experience of teaching the basics of engineering: calculus and the basics of physics as part of a project-and team-work initiative in the department of Electronics and Information Technology, at Copenhagen University College of Engineering (CUCE) in Denmark. All the basics courses in the first and second semester have been taught as part of projects and involve teamwork. Modern engineering students are difficult to motivate in order to learn pure theoretical issues such as solving differential equations. Especially when we talk about undergraduate engineering students, who do not expect to continue their education higher than a Bachelor of Science in Engineering. At the same time, and for the same reason, the fail rate in mathematics is very high during the first two semesters. This was the reason we decided to change the structure of our education and incorporate the theory with practical projects. This paper describes some of the projects. The projects are the motivating factors to learn mathematics. The examination results show improved learning potential, when using this method of engineering education. The students' evaluations show a very positive effect on their experience with this "practical" way of learning theory. At the same time, the evaluation results have shown higher pass rates and higher grading.**

Keywords - Motivation, Project based learning, Teamwork

I. INTRODUCTION

The research confirms improvement of the learning outcomes in education when the theory is combined with practical training or projects [3,5,8,10,13,14]. Usually the project-based courses are introduced after the students have passed the first 2-3 semesters of the engineering basics, like calculus, physics and computer programming. Students who wish to work professionally with electronics, computers and telecommunication, and who do not wish to continue for Master Degree, are not motivated to use 2-3 semesters for pure theoretical studies [11,12]. These students usually have high fail rate in mathematics and physics in the first 1-2 semesters and, as a result, many of them stop. On the other hand we must introduce the theory in order to understand and work with a number of complex engineering disciplines. Considering the students' wish to work with real engineering projects and the requirements to master the basics of mathematics and physics, the message is clear: the students will be more likely "to stick with derivatives and integrals" [6] if we can offer them some evidence of how necessary these tools are in order to find solutions for engineering problems[1,2]. If we use this strategy from the first semester the students will experience that they already make progress towards completing engineering work/projects and the positive influence will be shown in an increased pass rate. There are different possibilities to include experimental work together with theory in engineering [7,9,17] like:

1. Using simulations programs involving graphics and animations in order to visualize mathematics and physics.
2. Mixing the theory classes with laboratory exercises.
3. Study-tours to industrial companies.
4. Inviting guests from industry for lectures.
5. Make students to work with engineering projects in teams.

In particular the engineering students benefit from new technologies [4], as they actively use both Internet and simulation programs [20,21]. Teaching theoretical mathematics today is a very challenging task, even more so when we talk about undergraduate, practical oriented engineering students. The engineering students' expectations for their study program are more practical and experimental activities, then the calculations of the theoretical problems with pen and paper. Many universities and engineering colleges have the opinion that pedagogical activities must actively involve the students in order to motivate them to learn basics of mathematics and physics [17]. Problem-based learning and working with projects has already been implemented in engineering educations in many different universities [1,3,9]. This paper presents how we implemented the calculus and the basics of physics in the curriculum for undergraduates, as a part of projects in the first two semesters.

II. STUDY STRUCTURE

Some years ago, we went through the process to renew the educational study structure in our department and we decided to change the study structure in CUCE towards more projects and teamwork. Similar changes were made for all semesters in our programs, involving the basic courses in mathematics and physics. Example of our program in electronics and information technology is shown in Table 1.

TABLE I. EIT- STUDY PROGRAMME

ECTS	1. sem	2. sem	3. sem
2.5	Object Oriented Prog. 1	Object Oriented Prog. 2	Electromagnetism
2.5			
2.5	Project 1	Project 1	
2.5			
2.5	Mat1 (DSM1)	Mat2 DSM2	Mat1 (DSM1)
2.5			
2.5			
2.5		Digital Electronics 2	
2.5	Digital Electronics 1	Project 2	Projects
2.5			
2.5	Project 2		
2.5			

ECTS	4. sem	5. sem	6. sem	7. sem
2.5	DSM4	Practical Training	Elective	Bachelor-project
2.5				
2.5				
2.5			Elective	
2.5	Control Theory			
2.5				
2.5			Elective	
2.5				
2.5				
2.5	Robot-Project		Elective	
2.5				
2.5				

Project- based learning requires a high degree of concentration on particular topics, and in order to support this educational method we also changed the weekly time schedule. Students have only two modules/topics during one day, one from 8:30-12 and one from 12:30-16:00. Each module includes four lectures of approximately 45 minutes and some necessary breaks in between. The example of weekly schedule is shown in Figure 1. One module of tuition is usually related to a course of 5 ECTS credits, and one module of teacher tuition requires on average 4 hours of self-study for the student.

Mon	Tue	Wed	Thu	Fri
08:30-12:00	5 ECTS Credits			
12:40-16:00				

Figure 1. Weekly Schedule

III. FIRST-, SECOND- AND THIRD-SEMESTER MATHEMATICAL COURSES

The first semester mathematics course has the following content:

- Linear algebra, basics.
- Signals and systems.
- Complex numbers
- Number systems and number representation.
- Polynomials.
- Infinite series.
- Fourier series in continuous time.
- Differential equations, in project context
- MATLAB

The course has a value of 10 ECTS course with two modules per week. In connection with this course the students work in teams on projects connected to all the courses they have in the first semester. These projects give an additional 5 ECTS and are a mix of mathematics, digital signal processing, programming and digital hardware. Examples of first semester projects are:

- Development and implementation of the algorithm for Gauss elimination
- Development, programming and hardware implementation of the algorithm for an elevator's movement
- Apply differential equations in the description of a simple physical system and make a MATLAB simulation

During the semester, the students develop the following skills:

- how to work in teams,
- how to make a presentation for tutors and other teams on seminars,
- define and describe the fundamental problems and concepts introduced in the course – using proper mathematical notation,
- define and describe the fundamental methods for solution introduced in the course – using proper mathematical notation,
- define and describe a feasible algorithm based on a mathematical method for solution - allowing a subsequent implementation in MATLAB.

The second semester course in mathematics is a combination of Digital Signal Processing and discrete mathematics (DSM2). The content of this course is:

- discrete-time linear systems in the time-, frequency- and z-domains,
- design and implementation of digital filters on a digital signal processor including A/D and D/A converters,
- MATLAB used as simulation tool.

The projects connected to this course are concentrated on the following:

- set up specifications for the amplitude response of FIR and IIR filters,
- apply the design tools of MATLAB to calculate the filter coefficients,
- implement and test by measurements digital filters using a DSP evaluation kit.

The non-technical skills learned during the second semester's courses and projects are:

- how to work out written reports in connection to the course assignments and projects,
- how to collect information and acquire new information and knowledge,
- how to communicate technical problems in writing and speech,
- how to cooperate in teams.

The third semester courses combine mathematics, physics, and electromagnetism and circuit theory. Mathematical modeling is used as a tool to describe mechanics, electromagnetism and circuit theory involving differential equations.

The projects on third semester are more advanced, like:

- Specification, analysis and design of electronic scale. DC-project, (figure 2).
- Design of the metal detector, AC-project and filter design, (figure 3).
- Mathematical Modeling of the electronic scale, comparison between measurements and simulations (figure 4).

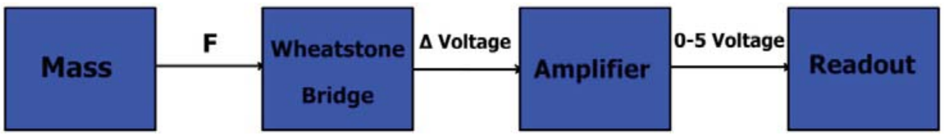

Figure 2. Block diagram of Electronic Scale, DC-project.

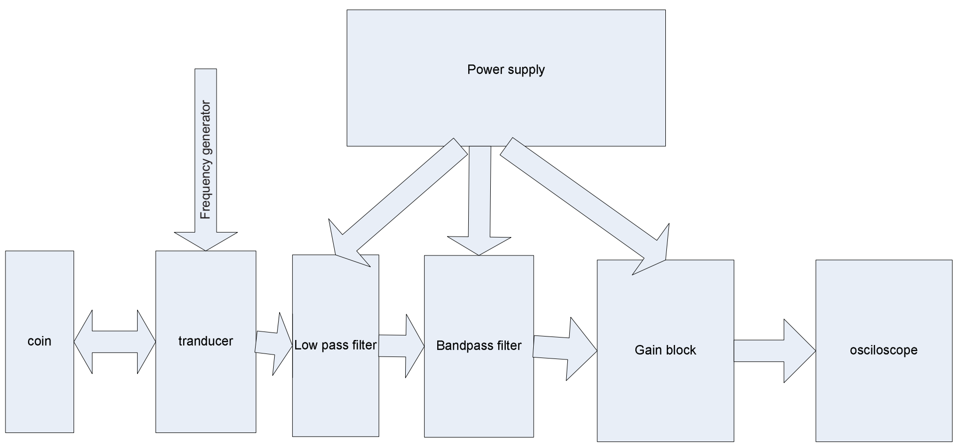

Figure 3. Block diagram of the metal Detector, AC-project

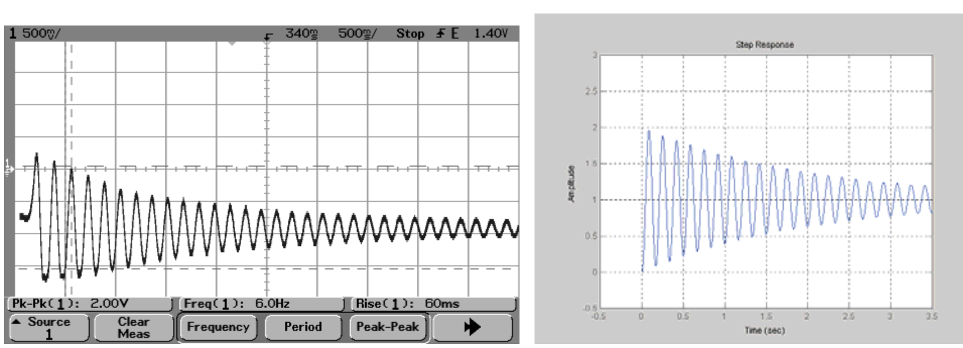

Figure 4. Electronic scale and simulation

The documentation of the practical design and experiments are described in the reports and give the basis for the evaluations of the projects on each semester. This is an advanced process of learning, where the students have the responsibility for combining the theory and practical electronics design [8, 9, 15]. The motivation to learn basics of mathematics and physics is improved, compared with traditional classical educational methods, where the students learn all the theory in pure theoretical courses during the first semesters of their education.

IV. THE EXAMINATION

The examination process in Denmark involves by law an external examiner certified by the Ministry of Education, for all examinations at the university level. For engineering departments the external examiner is very often a company manager. The role of external examiner, among other things, is to keep the engineering curriculum up to date. The external examiner has a great opportunity to discuss the contents of the engineering courses including: pedagogical methods, experimental work, and projects when he or she participates in the examination. The external examiner has to report his/her conclusions about the examination level, and the level of education to the chairman of the external examiners, who is approved by the Ministry of Education. This procedure gives the industry an influence on the engineering education in Denmark. The industry can easily have influence to change the engineering departments' curriculum according to the needs of the industry. On the other hand the students meet their future managers, and get the knowledge of the requirements in industrial companies at the same time.

The examination, for project related courses, is both group- and individual- examination, but the marking is always individual. The evaluation is based on a general impression of the level achieved by the student relative to the objective of the project based course. The examiners, teachers, and the external examiner have read the students' three reports in advance. The students present the results of their work, both as the oral presentation and as a practical demonstration of the hardware. The questioning, which is a part of individual examination, begins after their group presentations. After questioning, the students leave the examination room and the examiners discuss their presentations, as a group and as individuals. The marks are given individually, and the students, one by one are invited back into the examination room for the explanation of their marking. After the examination the students can evaluate the course anonymously on the Campusnet [18] (Figure 5). Campusnet is an intranet portal for students, teachers and university administration. It is also Course Management System, where all students can add and drop classes, view and print their schedule, manage their account, request transcripts, forward email, view grades, and more. Instructors and teachers can view their schedule, and view student information.

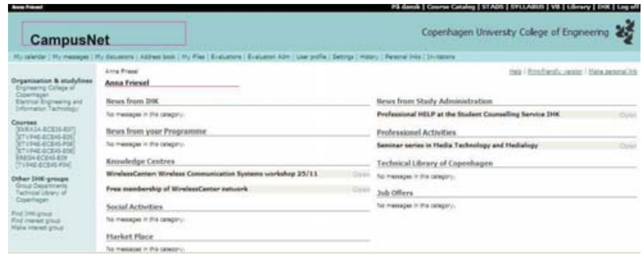

Figure 5. CampusNet at CUCE

V. STUDENTS' EVALUATIONS

Students make evaluation of theirs courses twice during the semester, in the middle of the semester and after the examination. The final evaluation, after the examination, is made on CampusNet and the results of this evaluation are available to the students participating in the course, the teachers and the head of the department. The evaluations include three parts: course evaluation, teacher's evaluation and general comments. The questionnaire is shown in Table II.

TABLE II. COURSE EVALUATION QUESTIONAIRE

Course evaluation
1. Target fulfillment:
To what degree has your learning measured up to the course description?
To a very high degree To a great degree To a suitable degree To a low degree To a very low degree
2. Your own performance
2.1 How much time do you estimate you have spent on the course compared with the expected time**?**
< 50% 50% - 70% 70% - 100% 100% - 130% > 130%
3. The relevance of the course:
To what degree do you consider the course relevant for your education?
To a very high degree To a great degree To a suitable degree To a low degree To a very low degree
4. The academic level of the course:
To what degree has the course challenged your academic abilities/competences?
To a very high degree To a great degree To a suitable degree

To a low degree To a very low degree
5. The study material:
To what degree has the study material supported your learning?
To a very high degree To a great degree To a suitable degree To a low degree To a very low degree
6. The teaching method:
To what degree has the teaching method supported your learning?
To a very high degree To a great degree To a suitable degree To a low degree To a very low degree
7. The test/examination method:
7.1 To what degree do you find that the examination method matched the method of teaching?
To a very high degree To a great degree To a suitable degree To a low degree To a very low degree
7.1 To what degree has your learning measured up to the course description?
To a very high degree To a great degree To a suitable degree To a low degree To a very low degree
7.2 To what degree do you find that the test/examination method is suitable for testing whether the objective of the course has been fulfilled?
To a very high degree To a great degree To a suitable degree To a low degree To a very low degree

Teacher's evaluation

1 The teacher's instruction in connection with the preparation of assignments:

1.1 How do you evaluate the quality of the academic instruction you received in connection with the preparation of assignments?

- Very good
- Good
- Satisfactory
- Poor
- Very poor

1.2 To what degree do you find the academic instruction you received, in connection with the preparation of assignments, to be sufficient?

- To a very high degree
- To a great degree
- To a suitable degree
- To a low degree
- To a very low degree

2 The teacher's instruction regarding teamwork, study methods etc.:

2.1 How do you evaluate the quality of the process instruction you received in connection with the preparation of assignments?

- Very good
- Good
- Satisfactory
- Poor
- Very poor

2.2 To what degree do you find the process instruction you received, in connection with the preparation of assignments, to be sufficient?

- To a very high degree
- To a great degree
- To a suitable degree
- To a low degree
- To a very low degree

3 The teacher's feedback on student work with assignments etc.:

3.1 How do you evaluate the quality of the feedback you received on questions, work with assignments etc.?

- Very good
- Good
- Satisfactory
- Poor
- Very poor

3.2 To what degree do you find the feedback on questions, work with assignments etc. to be sufficient?

- To a very high degree
- To a great degree
- To a suitable degree
- To a low degree
- To a very low degree

4 The teacher's presentation of the subject matter and ability to put into perspective:

4.1 To what degree did the teacher's presentation, summarizing and putting the new subject matter into perspective support your learning?

- To a very high degree
- To a great degree
- To a suitable degree
- To a low degree
- To a very low degree

4.2 To what degree do you find the feedback on questions, work with assignments etc. to be sufficient?

- To a very high degree
- To a great degree
- To a suitable degree
- To a low degree
- To a very low degree

General comments

1.1 What was good or worked well in the course?

1.2 What was bad or worked badly in the course?

1.3 What are your suggestions for improvements?

Table III shows the statistics of the first semester's evaluations. The results of this evaluation were as follows:

1. 68% of the students (who answered the questionnaire) were either very satisfied or satisfied.
2. 72% of the students felt that the teaching method supported their learning very well.
3. 84% of the students find that the test/examination method matched the method of teaching.

TABLE III. THE STATISTICS OF THE FIRST SEMESTER'S EVALUATIONS

1.Semester	Questionnaire	Total	Percent
ECD11	21	32	66%
ITD12	19	26	73%
ECD13	13	18	72%
ECE15	18	25	72%
ECE16	7	24	29%

VI. CONCLUSIONS

After several semesters of completed Project- and Team-Based basics courses in department of Electronics and Information Technology, we can make the conclusion, that the main objectives have been achieved. The students have got a better understanding of the mathematical tools in engineering. We have also observed much better understanding of more advanced engineering physics during the fourth semester of their education. The students' own evaluations show an increased motivation to learn mathematics and physics in this practical approach to the theory, especially for the students with previous practical experience. The examination results are shown in graph on Figure 6, it is clear that we have highly improved the pass rate for first and second semester students, and the overall dropout due to theoretical mathematics is much lower. The level of drop out after first and second semester is now below 20%.

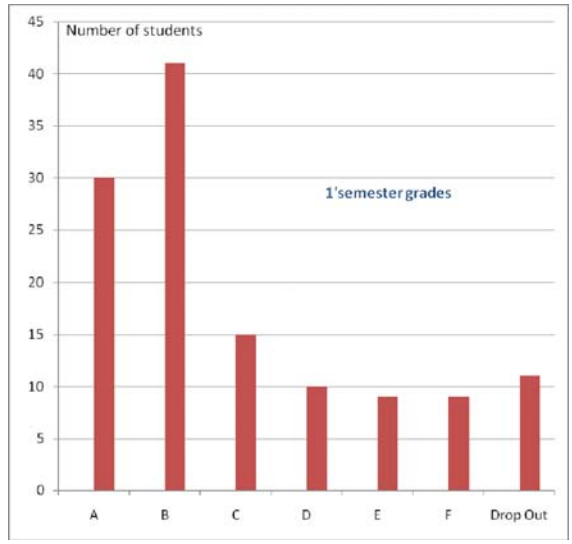

Figure 6. The examination results

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The Use of Role Playing in Engineering Curricula: a Case Study in Human-Automation Systems

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Abstract—**This communication presents a collaborative experience between four Spanish centers: the School of Engineering (ETSE) and the Sports Services Area (SAF) both from the Universitat Autònoma de Barcelona (UAB) jointly with two centers of the Technical University of Catalonia, the high school from Vilanova i la Geltru (EPSEVG) and the high school in Terrassa (ETSEIAT). The idea behind this collaboration is to explore the possibility of role engineering education and project development for engineering students. The basic principle of such projects is the identification of the corresponding roles associated with the different parts that can be found on current social/industrial activity.**

Keywords-component; role-playing; project-based learning, effectiveness and satisfaction metrics

I. INTRODUCTION

The Role Playing is used in our work as a methodological tool to provide students an appreciation of the range of issues and problems associated with engineering requirements in a real framework [1]. The Role Playing strategy is a successful tool used, for example, in software engineering education. The Role Playing is used in our work as a methodological tool to provide students an appreciation of the range of issues and problems associated with engineering requirements in real settings [1], [2]. An integrated framework is developed in order to improve the relationship between the Role Playing strategies inside the educational theory of Technological Pedagogical Content Knowledgement [3]. One interesting approach is to establish a relationship between the use of the role playing approach and the realization of an engineering project.

Among all possible different engineering curricula that can be found around (see [4] for a few examples) it is recognized the value of hands-on experiments and realization of project courses. Effectively, the realization of a project, usually during the last year of the degree, allows the student to face with a somewhat large problem where he/she has to be able to tackle the analysis and design stages as well as considerations on technology for implementation. The motivation for this communication is to show how opportunities for real world control and automation applications can be found on the immediate student environment.

This paper presents the application of the Role Playing methodology in engineering classroom from the point of view of an industrial automation case study. Finally we will explain the feedback of the SAF staff and the effectiveness of this method with the aid of well defined usability metrics.

II. INDUSTRIAL-ACADEMIC COOPERATION

The "UAB" is a campus based university with more than 40.000 inhabitants (students, academics, staff, etc). In fact, this makes the University campus to behave like a city with some sort of facilities offered for their inhabitants. Among them, the Sports Service Area (SAF) is one of the largest and with more complex installations [5].

Due to the evidence for the need of introducing new control elements and to integrate the different subsystems to help the SAF management staff the collaboration between both entities (SAF and the Automation and Systems Engineering Group) has emerged (see Fig. 1). The interesting point is that we decided to develop the collaboration under the form of engineering projects for undergraduate students.

Each academic year, before summer, it is time to prepare the engineering projects to be developed during the next year. This way the students can look at the different offers and present their applications.

From the SAF management a list of automation and control problems is first elaborated. From this list (jointly elaborated with the academics), a subset of problems that are realizable as an undergraduate project is identified and offered to the students. From this point students should apply for one project by presenting their CV and explaining the motivation and reasons for doing such project. Once the selection is done, a first joint meeting between the customer (SAF management), Project Direction (Academic staff) and Project developers (the students) is done.

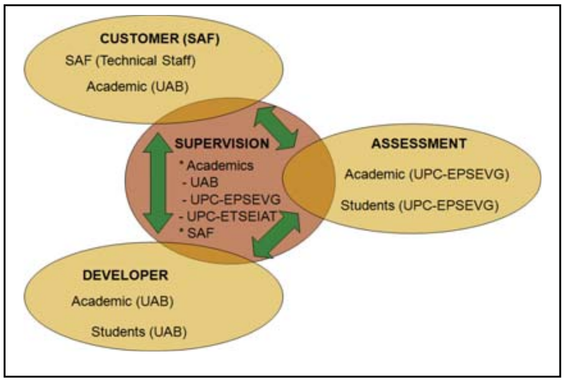

Figure 1. Identified roles and intercation between partners

From this point each student has a calendar of meetings (usually every 15 days) between him, the SAF management and the academics associated with the project. If any of the projects needs to collaborate with the work being developed on another project, there is a joint meeting where each one exposes their needs in order to find a joint solution.

Due to the evidence for the need of introducing new engineering system elements and to integrate the different subsystems to help the SAF management staff the collaboration between external entities has emerged. In this context, the SAF entity plays the customer role (maintenance functions), the ETSE member plays the software development role (monitoring and control interface), the ETSEIAT member provide us with the project-based learning approach and the EPSEVG member give us the human-centred automation approach [6]. The control engineering students from EPSEVG center have assigned the following roles: software developers (in order to build new supervisory control interfaces), designers (in order to apply ergonomics recommendations to display design), project management and usability engineers (in order to prepare usability testing and measure efficiency, effectiveness and satisfaction of the SAF human supervisors).

III. Engineering Students in the Role of Human Operators

From the framework described in the preceding section as the starting point, the experience is now driven one step forward and a third element is introduced: the external assessment role. The motivation for the introduction of this factor and force it to be developed on a different university (therefore geographically distributed and from a different educational framework/environment) is to create an atmosphere as similar as possible to the one the students will face within their professional life. The total interacting group is therefore constituted of three teams. Each team has a leading academic and a group of students. In addition, each team has associated specific roles corresponding to the professional activity they have to play. The development of such roles is mainly based on scientific and technological skills. These skills will be supervised and evaluated by the corresponding leading academic. In addition, other cooperation and interpersonal skills are to be considered. These skills (Table I) will be considered by a team that integrates the leading academic members of each team. The relevance of effective teamwork is very important in the successful operation of control room environments. According to this idea it's necessary to define a set of competencies [7].

TABLE I. Competencies Required For a Control Room Operator

Potencial competencies
Have a good knowledge of drills and procedures
Be able to operate control equipment accurately
Understand the theory andd application of the control process
Understand the safety aspects of control room operations
Be able to make appropiate decisions
Be able to assess a situation accurately
Be able to deal with stress and time pressure
Ensure that team goals, roles and responsibilities are understood
Be able to anticipate colleagues' requirements
Be able to pass the correct information to colleagues at the right time
Be able to notice overloaded colleagues and support them appropriately
Be able to think ahead and develop cintingencies
Ensure that colleagues maintains a shared understanding

The research in team training has been focused on training the members of a team together as a composite unit. The control engineering students from the EPSEVG center have the following roles: software developers (in order to build new supervisory control interfaces), designers (in order to apply ergonomics recommendations to display design), and usability engineers (in order to prepare usability testing and measure efficiency, effectiveness and satisfaction of the SAF human supervisors). At the EPSEVG center, a production systems laboratory that incorporates a Flexible Manufacturing System (FMS) is available. The control engineering students work in 2-people groups. Each group has a role inside the academic FMS and receives training about display design and systems maintenance.

This paper presents the application of the Role Playing method in engineering class from the point of view of an industrial automation case study in the following terms:

- One engineering student (Msc Automatic Control and Robotics from the Technical University of Catalonia) in the role of control room designer have been developing a new SAF layout in order to identify all the tasks (supervisory control, maintenance, display design and usability testing). This student made a meeting and a questionnaire with the SAF staff in order to obtain information about the physical and mental workload (see subsection A below).
- Some engineering students (MsC Engineeering in Automation and Industrial Electronics from technical school EPSEVG and ETSEIAT) have been using the display design ergonomics guideline (GEDIS guideline [8]) in order to improve the interface

quality. In these moments, one student is programming these changes in order to improve the quality of the SAF monitoring interface (see subsection B).

Finally we will present the feedback received from the SAF staff and the effectiveness of this method with the aid of well defined usability metrics as well as future steps [9].

A. Supervisory control task in the SAF Project

After a meeting among the SAF manager staff and the external assessment, it is necessary to show the SAF manager staff a set of important recommendations along the lines of the following:

- Train maintenance operators in supervisory control tasks (monitoring and alarm systems)
- Improvement of the feedback between the manager, the maintenance operators and the software developers
- Re-design the control center layout in order to define a control room (see Fig. 2). It is necessary just to establish the functionality for each room and translate the meetings inside a meeting room.
- Improve the display design quality, by using, for example, an ergonomic guideline

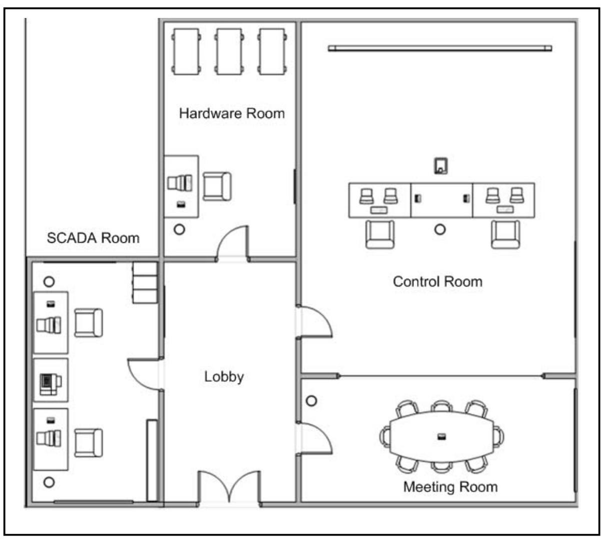

Figure 2. An engineering student (MsC Automatic Control and Robotics) in the role of control room designer: after a meeting and a questionnaire with the SAF staff, this is a possible SAF layout in order to differenciate all the tasks (supervisory control, maintenance, display design, usability testing)

B. SAF display evaluation

The experimental study is the evaluation of the SAF interface with the collaboration of control engineering students from Technical University of Catalonia. From Vilanova i la Geltrú city, twenty five students monitored the SAF interface for three weeks. The students assign a numeric value to each indicator of the GEDIS guideline [8] and propose interface improvement.

The GEDIS guide is a method that seeks to cover all the aspects of the interface design [9]. From the initial point of view of strategies for effective human-computer interaction applied to supervision tasks in industrial control room [10], [11].

The GEDIS guide offers design recommendations at the moment of creation of the interface as well as recommendations of improvement for already created interfaces.

The GEDIS guide is composed of two parts: description of ten indicators and measure of ten indicators. The indicators have been defined from extracted concepts of other generic human factors guidelines, and from aspects of human interface design in human computer interaction. As an example, included indicators are: architecture, navigation, alarm design, use of color and text, human operator inputs, etc.

TABLE II. GEDIS GUIDE INDICATORS (PART I)

Indicator name and Subindicator name	**Numeric/qualitative range and SAF numeric value**
Architecture	**1,7**
Map existence	[YES, NO] [5,0] 0
Number of levels le	[le<4, le>4] [5,0] 0
Division: plant, area, subarea, team	[a, m. na] [5,3,0] 5
Distribution	**3**
Model comparison	[a, m. na] [5,3,0] 3
Flow process	[clear, medium, no clear] [5.3,0] 3
Density	[a, m. na] [5,3,0] 3
Navigation	**3**
Relationship with architecture	[a, m. na] [5,3,0] 3
Navig. between screens	[a, m. na] [5,3,0] 3
Color	**5**
Absence of non appropriate combinations	[YES, NO] [5,0] 5
Color number c	[4<c<7, c>7] [5,0] 5
Blink absence (no alarm situation)	[YES, NO] [5,0] 5
Contrast screen versus graphical objects	[a, m. na] [5,3,0] 5
Relationship with text	[a, m. na] [5,3,0] 5
Text font	**3,2**
Font number f	[f<4, f>4] 5
Absence of small font (smaller 8)	[YES, NO] [5,0] 0
Absence of non appropriate combinations	[YES, NO] [5,0] 5
Abbreviation use	[a, m. na] [5,3,0] 3

TABLE III. GEDIS GUIDE INDICATORS (PART II)

Indicator name and Subindicator name	Numeric/qualitative range and SAF numeric value
Status of the devices	**4**
Uniform icons and symbols	[a, m. na] [5,3,0] 3
Status team representativeness	[YES, NO] [5,0] 5
Process values	**3**
Visibility	[a, m. na] [5,3,0] 3
Location	[a, m. na] [5,3,0] 3
Graphs and tables	**4**
Format	[a, m. na] [5,3,0] 3
Visibility	[a, m. na] [5,3,0] 3
Location	[a, m. na] [5,3,0] 5
Grouping	[a, m. na] [5,3,0] 5
Data-entry commands	**3**
Visibility	[a, m. na] [5,3,0] 3
Usability	[a, m. na] [5,3,0] 3
Feedback	[a, m. na] [5,3,0] 3
Alarms	**3,8**
Visibility of alarm window	[a, m. na] [5,3,0] 3
Location	[a, m. na] [5,3,0] 3
Situation awareness	[YES, NO] [5,0] 5
Alarms grouping	[a, m. na] [5,3,0] 5
Information to the operator	[a, m. na] [5,3,0] 3

Where a=appropriate, m=medium, na= no appropriate.

The method to continue for the application of the GEDIS guide is: to analyze the indicator, to measure the indicator, obtain the global evaluation index and, finally, offer recommendations of improvement. The computation of the GEDIS guide global evaluation index is done according to the following formula:

$$Global\_evaluation = \frac{\sum_{i=1}^{10} p_i ind_i}{\sum_{i=1}^{10} p_i} \quad (1)$$

In a first approach the mean value among the indicators expressed in (1) has been considered. That is to say, to each indicator an identical weight ($p_1 = p_2 \ldots = p_{10} = 1$) has been assigned, although this will allow, in future studies, to weight the importance of some indicators with respect to others. The global evaluation is expressed in a scale that ranges from 0 to 5.

For the correct use of the GEDIS guide it is necessary the collaboration between the control room technical team and the human factors technician, since in some cases to analyze the indicator it is necessary to consider the expert's opinion.

The SAF interface global evaluation GEDIS index is 3.4. So it is necessary to indicate the SAF designer a set of important recommendations for further improvement:

- Revise the relationship between architecture, distribution and navigation indicators
- Improve the feedback between interface and human operator in data-entry commands indicator
- Improve the location of alarm indicator

With the GEDIS guide it is also possible to indicate the SAF designer a set of important recommendations about graphical screen improvements. For example, the *Piscina ACS* screen can be improved with a set of changes in color and text font indicators. Fig. 3 shows the original *Piscina ACS* screen and Fig. 4 shows revisited *Piscina ACS* screen.

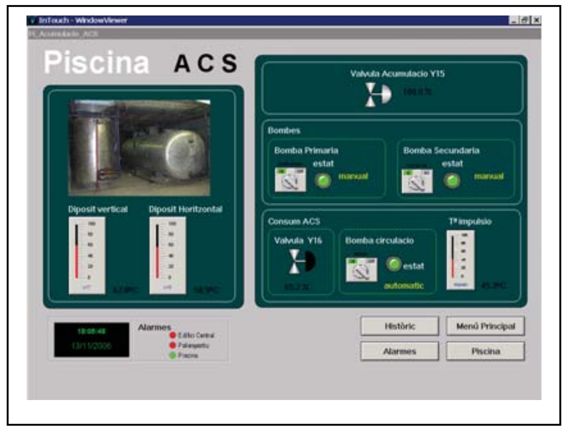

Figure 3. Original Piscina ACS screen (Catalan language)

Figure 4. Piscina ACS revisited with changes in color indicator (Catalan language)

In order to evaluate the effectiveness of the venture from the educational perspective, at the end of course 2008-2009 the students from *Integrated Production Systems* subject (IPS subject from the technical school EPSEVG) answer an adaptation of the Student Evaluation of Educational Quality Questionnaire (SEEQ):

- The students prefer dynamism in the class: more practical problems and less theoretical lessons.
- The students prefer to increase the number of laboratory sessions.
- The students think that the workload of the Msc Engineering in Automation and Industrial Electronics is high. Usually, these students work and don't have much time to do homework for their University Studies.
- The students are satisfied with the evaluation/assessment of the subject.

Fig. 5 shows one of the items related to the learning process.

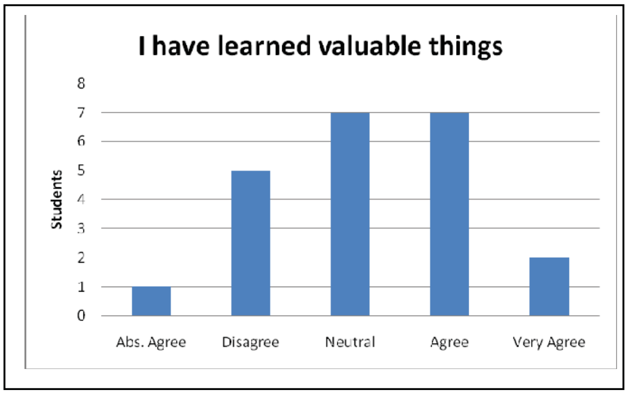

Figure 5. Inside the SEEQ "Learning" category (question two)

In order to evaluate the categories (Learning, Organization, Group Interaction, Examinations, and Assignments) the Table IV shows the comparison between some answers (only Good and Very Good answers) between the year 2006 and the year 2009. The questions are:

- Learning: A4 You have learned and understood the subject materials in this course
- Organization: C4 Practicum classes are useful and well prepared
- Group Interaction: D1 The own team and the other teams are a good tool to share ideas and knowledge
- Examinations: G2 Methods of evaluating student work are fair and appropriate
- Assignments: H3 Practicum tasks in the laboratory, contribute to appreciation and understanding of the subject

The Group Interaction assessment between the 2006 IPS Subject and the 2009 IPS Subject are similar. In the other categories, we can observe the increase in the 2009 subject students' assessment.

The next section shows a framework in order to introduce quality models concepts inside the engineering learning process.

TABLE IV. COMPARISON BETWEEN SOME ANSWERS

SEEQ Category	2006 IPS Subject	2009 IPS Subject
Learning		
A4	75%	80%
Organization		
C4	55%	80%
Group Interaction		
D1	78.9%	70%
Examinations		
G2	26,3%	60%
Assignments		
H3	36,3%	89%

IV. METRICS FOR EVALUATING HUMAN-AUTOMATION INTERACTION

An example of methodological framework is the Process Model of the Usability Engineering and the Accessibility MPIu+a developed by Toni Granollers [12] which gathers together all the cycle phases: requirements' analysis, design, implementation, launching, prototyping, evaluation and user,. The analysis of requirements is a necessary previous research work in order to establish the best relationship among the human, the interface, and the task. For example, which is the user's profile? A human in the role of maintenance staff or supervisory control operator or display designer.

In the evaluation phase, and for the usability measure, it is necessary to have the contribution of the experimental studies carried out in the usability laboratories. The problem is how to define common metrics for human-automation interaction because each task and each automation system has singular properties (chemical control processes, flexible manufacturing systems, oil control processes, etc.) [13]. another problem is: which is the best interface, from the point of view of the user's experience? Some interfaces are appropriate for a few users but not for all users.

In human-computer studies it is necessary to define qualitative and quantitative performance rates. Following some ideas of the experts in usability studies and field studies, the tasks presented in the previous section demand a high level of activity planning that involve reasoning and decision making. It is possible to follow different approaches: the *individual differences* approach, the *case study* approach and the *system characteristics* approach. In this paper we follow the first approach. The studies of user's differences have diverse goals:

- To find ways of predicting performance
- To find and characterize individual variability. To find not only differences in the degree to which users are able to reach the goals, but also differences in how they perform, i.e. decision making strategies and user satisfaction

From the point of view of usability engineering the proposed performance method can be summarized in three steps [14], [15]:

- Effectiveness measure
- Efficiency measure
- Users' satisfaction measure

Effectiveness is a measure of how well a human accomplishes the supervisory control task. For efficiency measures we find the ISO definition: "resources expended in relation to the accuracy and completeness with which users achieve goals" [16]. Effectiveness and efficiency measures are objective measures. For satisfaction measures we find user's questionnaire in order to achieve attitudes towards the use of the interface (how difficult is to learn the use of the interface, user's experience of discomfort in using the interface, etc.) [17].

Finally it is possible to define usability metrics. The number of attributes in usability engineering is three.

Attributes A = [Efficiency Effectiveness Satisfaction]

In the case of objective measures, it's possible to add these attributes inside (2)

$$Usability = \frac{\sum_{i=1}^{m} A_i}{m} \qquad (2)$$

The experimental session was carried out in the meeting room of the SAF enterprise at the Universitat Autónoma of Barcelona in December 2008, the two SAF staff members (maintenance head, computer science engineer) participated in an interview with a control engineering student playing the role of usability expert, they used the SAF display in a brief session in order to detect a possible device fault, and finally they answered a questionnaire about user interface satisfaction.

The questionnaire of the user interface satisfaction has been based on diverse classic references for this type of tools, for example the QUIS questionnaire [18]. The questionnaire has six questions related to the task where the user answers in concordance with the scale of Likert [19] with four answer options per question. Moreover, one more question has been added where the user assesses in a qualitative way the quality of the graphic display.

The six questions considered were:

- The task was difficult to understand
- The task has been long
- I have been confused, without having clear what it was necessary to do
- I needed to be very concentrated to carry out the task efficiently
- I have been pressured by the time
- I think that my performance has been correct

From the point of view of the maintenance head, the task is easy because he has great experience in process control and in fualt tolerant control. From the point of view of the computer science engineer the task is difficutl to understand for a novice user in process control and it's necessary to change some functionalities inside the screens in order to improve the quality of the supervisory control application (in example, the creation of an alarm system).

V. Conclusions

This paper has presented an experience that introduces a collaborative framework for undergraduate engineering project development. The idea presented here is based on representing the existing roles present in a professional framework with the additional value of integrating players from different universities and an industrial partner that provides services to the community. It is shown, among other points, how (i) the university itself can provide the customer points of view, (ii) promote collaborative work between different individual student projects within a global, large, project (iii) provide collaboration among different educational frameworks.

We will continue this work with usability testing in order to measure effectiveness, efficiency and satisfaction metrics over SAF supervisory operators. From the point of view of the authors, it's possible to apply the Cognitive Walkthrough method in order to obtain an analysis' task.

The SAF computer science engineer is assessing the use of the GEDIS guide in order to introduce changes and improve the quality of the graphical interface.

With the aid of well defined metrics and data collection it's possible to begin a statistical analysis as a future step of our work.

Finally, is necessary extend our approach in order to apply these methods to other subjects of the engineering curricula, study multiple roles, such as engineer-manager and find methods that help students to move from novice to expert.

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A Learning Approach Based on Robotics in Computer Science and Computer Engineering

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Abstract—**It is well known that the number of students that arrives to engineering studies decreases every year, due to the difficulty that these studies present, when compared to other studies, in a society that tends to be more social oriented than in the past.**

In order to increase the interest of the students this paper presents a Project Based Learning (PBL) that involves hardware and software using the robotics as the main object in computer studies. This educational project is being held in the Computer Science and Computer Engineering studies of the *Universitat Autònoma de Barcelona*.

Keywords-component: Project Based Learning (PBL), robotics in computer science/engineering.

I. State of the Art

The use of robotics for teaching purposes has motivated several generations of professors and students in computer studies. In 1994, Pattis et alt. presented *Karel the Robot* [1], a simulator to introduce programming techniques. From there up to now, several companies have introduced in the market excellent robot kits for education as Lego Mindstorms [2], Sony with Aibo [3], etc, based on robots that are programmed using specific tools. More recently, the Institute for Personal Robotics in Education and Microsoft presented the Myro robot [4] with an educational environment that has been extensively used to introduce students in engineering studies. Also, several authors [5] [6] have argued the use of robotics as a means in order to help the student in programming courses.

Until now robots have been extensively used in learning stages as a resource to improve teaching results, but rather limited to specific areas of knowledge. The robot, as a whole, is a powerful tool that can be used in transversal teaching processes. In this sense, engineering studies have a lot of transversal subjects that can be explored using the robot as a resource. Usually, the robot has only been used as a helping tool in the learning of programming techniques. The technological power that a robot presents has not been used as a whole in computer studies.

A. A PBL based in robotics in Computer Science

The paper shows a transversal experience that uses the technological power included in robots in a learning process in computer studies that includes hardware and software. Topics are introduced in a way such that students are confident with what computer studies imply despite the use of the robot. Robotics is only the "toy" for motivating the beginner students on the subject.

Of course, a PBL based in robotics in computer studies can include many topics comprising subjects from the first year to higher level courses. In the first year the robot can help to introduce basic topics taking as a basis the duality hardware/software (fundamentals of computer science, machine programming, programming techniques, programming languages, introduction to operating systems, etc.). At higher level courses, artificial vision, neural network and fuzzy programming, real time applications, human-computer interfaces, software engineering, etc. are typical subjects were robots are used as a resource. Robotics embraces all the computer engineering and computer science knowledge [7].

In this experience, the authors have used robotics in the first course as a resource to motivate the beginner students. In this sense, the robot has been used to introduce, hardware and software topics. The experience developed includes the subjects of fundamentals of computer engineering including low level programming (assembler), algorithms and high level programming and data structures.

The paper presents the experience that is being developed in our university. The explanation begins with a discussion in section two of the first course syllabus in computer studies and its adaptation to a robotic-based PBL. Section three introduces the scheduling of the reported experience. The setup and cost of the experience is discussed in section four. Section five describes the PBL application and results obtained and, in the end conclusions are presented.

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II. A SYLLABUS FOR A ROBOT-BASED PBL IN COMPUTER STUDIES

A. *Syllabus in the first course of computer studies*

The experience developed in this paper is being hold in the first course of computer studies in the Universitat Autònoma de Barcelona. The subjects of the computer studies are defined in the student guide. Table 1 resumes the topics covered in the student guide during the first year of entrance in the university. The table shows that the main involved topics are software, hardware, mathematics and an introduction to electronics. In fact, this curriculum, with little changes, corresponds to a typical first course in computer engineering / computer science studies in Spain.

A first glance to this curriculum shows that it could be a tough course for students that arrive to the university. Near the half of the topics are related with computer studies but they are not strictly computer science topics. That is, a significant part of them are mathematics and electronics. Professors are aware that these topics are not really pleasant to first year students. Many of these students are used to work with computers only to chat with friends or to play games.

Furthermore, the decrease in the number of students that arrives to computer studies (and into engineering in general) worsens still more the panorama.

In this sense, the authors are aware that it is necessary to motivate first year students. A method to improve it is introducing new educational methods that help to improve the motivation in first year students as, for example, using a robot as a motivating resource in the studies.

TABLE I. COMPUTER ENGINEERING FIRST COURSE SUBJECTS

Programming languages & Algorithms (105 hours)	Programming languages Functions and procedures Pointers Files Algorithm analysis Search and ordering algorithms Recursive algorithms
Data structures (60 hours)	Object oriented languages (C, Python) Lineal data structures Non lineal data structures: trees Other non-lineal data structures
Computer fundamentals (90 hours)	Digital systems: information representation, Boolean algebra, combinational and sequential circuits CPU fundamentals: architecture, instruction set, address modes, assembler, interruptions CPU peripherals: memories and memory hierarchy, input/output, Communications
Electronics (120 hours)	Electrical circuit basic laws Permanent and transient analysis Semiconductors: diode, transistor, opamp Technology: bipolar and MOSFET Introduction to data acquisition
Algebra (105 hours)	Matrices, vectorial spaces, linear applications, rings, polynomial operations
Calculus (120 hours)	Differential calculus and differential equations, integration, Fourier fundamentals

B. *The robot for a PBL in computer studies*

The robot is a perfect tool to introduce and to motivate students into computer studies. The robot is a packed unit that contains all the components and structures to introduce students to computer fundamentals and computer programming in a first year course. All subjects can be exposed using the components and the structure of the robot.

Software is the first great subject students learn in a first course in computer studies. At this level, the robot can be used to model any behavioral conduct, programming it using a high level language. Typical languages used in computer studies (talking about the learning of algorithms or data structures) spread from the classical C to more actual languages, as Ruby or Python for example. The main routines can be programmed into the robot, or the robot can be a slave that performs accordingly to actions mastered by the computer. This later case implies that the computer request the robot its sensors state, make decisions and sends actions to the robot. In any case, an algorithm could be implemented in the robot and data structures must be used.

At the hardware level (the second great subject) the kernel of the robot can be exploited to introduce computer hardware fundamentals. Simple robots are based in known microcontrollers. Scribbler is based on a PIC microcontroller. RUAB1 (our own robot) is based on an Atmel microcontroller. Deep in the microcontroller there is a typical CPU core, memory and peripherals that can be used as examples when computer fundamentals are introduced. Of course, any of these robots can be used in a PBL in computer studies.

In the planning stage professors must be aware that not all the robots perform correctly with the competences and with the didactics established for the course. For example, in our first year application of the PBL we used the Scribbler robot. Scribbler showed to be a gentle robot when used in software problems/projects. But when we tried to use it in a mixed hardware/software PBL we had to solve some not evident problems because the robot lacks of facilities to incorporate hardware in its core. Furthermore, the robot architecture is based in a PIC microcontroller which internally interprets the pBasic, the language used to program the robot behavior. Furthermore, the PIC CPU core is a rather tough CPU to introduce students to computer hardware fundamentals.

The third topic involved in the first course is electronics. Electronics is the basic subject that is behind the functioning of any electrical device. The robot is a perfect example to introduce the subject. All (not mechanical) devices in the robot work accordingly to the electrical rules. Thus, electronic basics and devices are introduced using as examples the different components of the robot in case studies.

In the end, mathematics is a subject that covers an important part of the first course studies. Maths can be introduced in a PBL through calculus equations and modeling approaches. However, and due that maths are not fairly related with hardware and software subjects, in this first experience they has not been involved in it.

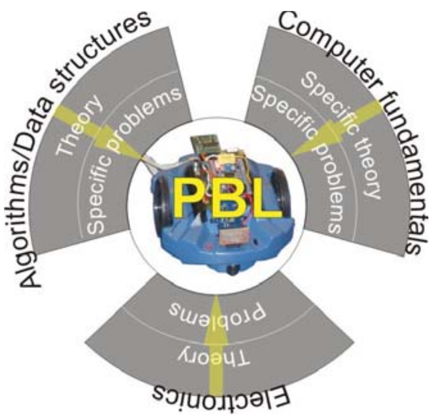

Figure 1. PBL scheduling

III. PBL SCHEDULING

A. Subject scheduling for a PBL in the first course of computer studies

The PBL approach is done in the first course studies of computer engineering in a subgroup of 20 students. In fact, this is a reduced set of the total number of students that enters in computer engineering studies, more than 100 students. The reason to do the experience with only a subgroup is that the cost that would imply to address to all students is not affordable neither recommendable in a first year experience.

So the project has been developed for a group of 20 students that voluntary decided to participate. The condition imposed to PBL instructors is that all the students of the course must acquire the same competences independently of the educational method carry out during the course. In order to achieve this, a planning of the course was made according to a study about the methodology used in each subject (Fig. 1) and the requirements imposed by the PBL:

- Theory is adapted in the subjects for the PBL students whenever it is necessary. This involves mainly the subject of computer fundamentals that needs to be reviewed in order to address the experience, and affects digital systems part as also the classical part of computer fundamentals. In what refers to digital systems topics, as they are not directly involved in the project, the subject is taken out of the PBL. So, this subject is given with the rest of the students. The more classical part of computer fundamentals (introduction of the CPU, memories, peripherals, etc.) is reviewed in order to fit the AVR architecture (the ATmega128 is used in the practical classes) in the computer fundamentals theory.
- Problems of each subject were adapted to the robot architecture in both hardware (except digital systems problems) and software. Problems are rearranged in order to fit with the PBL and with the devices that compound the robot.
- In the end, theory and problems focus towards a final project in which students must demonstrate the acquired skills in software and hardware. The hardware practical lessons were all reviewed in order to fit with the robot expertise that students must acquire. The software is more versatile and, with little changes practical lessons are adapted to control the robot. In the end, hardware and software are joined in a robot guiding problem/project. In it students must demonstrate that have developed the course skills in software and hardware.

B. Components of the PBL

The project to be developed by students comprises elements that address software and hardware subjects. This is accomplished using:

- A host to control the robot. In the host the students must implement high level algorithms to control the robot. Such algorithms are responsible of the robot behavior: line follower, light dependent tendencies, avoiding obstacles, guiding problems, etc.
- Fundamental computer hardware set on the robot. The student works on ATmega128 microcontroller in order to implement a low level hardware that fits with computer fundamentals subject. The objective to the final practice is that robot must send to the host the orientation of the robot. The task of the microcontroller is to send this message. The task of the student is to take expertise with the CPU and assembler language using this finality. So, a low level driver must run in the microcontroller and send data to the robot brain. To do this, in this first year experience students developed an orientation driver based on a compass sensor. In the end, the students must be confident with the microprocessor concepts introduced in computer fundamentals subjects.
- Introduction to elemental communication protocols can also be introduced in the PBL. In this case. The communication between the host and the robot is performed via RS232, a low level protocol easily understandable by first course students.
- At the software level students may introduce a high level conduct into the robot. In this case, the robot must run in a labyrinth with doors that have to be opened asking for a key.
- In the end, and though many good wishes always are expected, instructors were confident that the work in real time is difficult. In order to overcome it a setup based on a camera in the final practical lesson is prepared by authors in order to help the robot to follow the path.

IV. SETUP AND COST OF THE EXPERIENCE

If the aim of the experience is the motivation of students in a career, professors cannot expect to obtain it without investment. Of course, a teaching experience using robots has an important associated cost due to the need to work with robots. In this experience a robot is lend per group of students (2 persons per group). During the course students have the robot and can work with it at home. In the last class, students brings back the robots and in a plenary session must demonstrate the software and hardware knowledge and competences acquired by means of the evolution of the robot in a competition. Teachers think that this is a good strategy in order to increase the motivation of the students.

The market offers several robots that can be used in the experience. Scribbler is one of the last introduced educational robots. It is nowadays used in a lot of learning experiences. Associated with Scribbler useful software can be downloaded without any cost. We used Scribbler in this first year application of the learning approach, but we had to tune the robot in order to adequate it to our mixed hardware/software experience.

That is, Scribbler is adequate if the experience is to be held using only a software approach. The robot has enough devices (sensors and actuators) to create good software programming projects in order to achieve good learning skills in software. However, when the experience takes as a basis a PBL using hardware and software topics, the robot lacks for facilities for interfacing hardware elements on it.

In order to introduce computer fundamental topics additional hardware was built and mounted over Scribbler (see Fig. 2). Of course, this implies that (in addition to the hardware changes) several software changes are introduced in the Scribbler software kernel in order to work with the new hardware.

So, the cost of the experience is the sum of the costs of the robot plus all the elements introduced in order to realize the programmed PBL. It consists of:

- The robot. We used a Scribbler robot.
- Additional hardware mounted on the robot. It was necessary in order to introduce the computer fundamentals subject in the PBL experience. It is based in an ATmega processor, the compass sensor and related passive components.
- A serial-Bluetooth connection between the robot (that acts as a slave in our experience) and the host (a PC). So, the host and the robot can communicate via the simple UART port of the ATmega board and the PC in a wireless way.

Figure 2. Robot and tuning

Figure 3. Practical setup

- A setup based on a vision guided program introduced in the host in order to help robots in the final session.

The first three items correspond to the hardware that students take in a leasing form during the course. The fourth item is built for the setup of the PBL (see Fig. 3). In it students practice during the course and make the final examination.

And though it was not yet namely, surely, the more expensive item is the cost in people involved in the experience. During the PBL planning and developing, the people involved in the experience must foresee to spend a lot of hours trying to get along the hardware components in the robot and the projects to be done by students with the robots. It was rather cumbersome to get all the components working together because of:

- The physical connection at the hardware level. Scribbler only has a port that can get free in order to allow any hardware connection to it. It is the hacker port, used only to control three LEDs. In it we connected the ATmega microcontroller, responsible of two main tasks: to control the orientation behavior of the robot and to perform the communication with Scribbler.
- The software communication between the robot and the hardware just added. In order to work with the data sent by the ATmega that gives the orientation of the robot, communication between the low level language (assembler) of the board and the high level language (Python) in the host has to be established via the PBasic language interpreter running in the PIC.

V. PBL APPLICATION AND RESULTS

The PBL in robotics has been introduced in the Computer Science studies. During the school year students work with the different subjects with the finality to joint in the hardware and software learned topics in the final session demonstration. The qualifications of the subjects are composed of the theoretical qualifications, obtained in a written examination for each subject, and the practical qualification that is unique for all the subjects participating in the PBL.

Fig. 3 is a picture of the final class of the PBL in robotics. The main components of the PBL can be recognized in the picture:

- The robot is the kernel of the PBL. In this first year experience a tuned Scribble robot was used. On the robot there is a landmark to help tracking the pose of the robot with a camera
- The camera setup of the experience. A host follows the path of the robot via a camera in order to help the robot in its movement. We introduced this improvement once we realize that real time programming can be rather frustrating for novelty students.

In respect to the results of the PBL experience several comments can be stated:

- Academic results were rather good. Students acquired the established PBL skills (knowledge and competences) in software and hardware. Students get also aware that they get with the particular competences stated in each subject.
- Students get also self satisfied with the experience
- And several students commented to the instructors that their self regard had grown.
- However, students also said that the experience was hard.

VI. Conclusions

This paper resumes a robot-based PBL experience joining hardware and software subjects in the learning process. The experience has been done in the first course of computer engineering studies with the aim to motivate first year computer engineering students.

The conclusions of the experience are:

- The kernel of the experience is the unification of software and hardware topics in a project. The aim is the motivation of the students. The objective is achieved and also has been fruitful.
- The authors are satisfied with the expertise demonstrated by the students at the end of the experience. The main learning topics were introduced and the students passed with qualifications the course.
- A poll made to students reinforced that students were satisfied with the experience. Students were aware of the knowledge acquired during the course.
- The success of the experience has been demonstrated. But a lot of hours must be dedicated by professors in the setup of the whole experience.
- Perhaps the most critical part of the whole experience has been the need to work with different hardware resources. As introduced, a tuning of the robot had to be done in order to coordinate hardware and software practical classes. In order to improve this, the authors are developing this year the experience using RUAB1 a robot specially designed and built for the PBL activities. It is based in an ATmega microcontroller and for the PBL has a clear advantage: all the hardware and software topics can be done using a unique microprocessor.

Acknowledgments

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Session 07D Area 2: Laboratory Experiences: on-site and remote environments - On-line Labs

NETLAB: Online Laboratory Management System

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Reconfigurable weblabs based on the IEEE1451 Std.

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The Montegancedo Astronomical Observatory. The first free remote observatory for learning astronomy

Cedazo-León, Raquel; López-Zamarrón, Diego; Sánchez-Moreno, Francisco Manuel; Sebastián-y-Zúñiga, José María

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NETLab: An Online Laboratory Management System

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***Abstract* - Online hardware-based educational laboratories are increasingly being deployed in traditional on-campus as well as Web-based distance-learning courses around the world. An online laboratory generally will consist of several hardware-based remote experiments. However, one particular experiment can be performed at a time by an individual student or a group of students which require a careful scheduling of the experiments. For the proper implementation of an online laboratory an efficient laboratory management system (LMS) is thus essential. Also for an online laboratory, the students need to fully understand the experimental system setup and feel comfortable as in an actual laboratory environment which, however, can be effectively done by adding suitable videos and animations etc. Besides, the students should be able to run the remote experiments, extract, save and analyze the data and submit laboratory reports online. The front end of the laboratory management system should be made browser-based so that one can use the laboratory facility from anywhere. Also, for the teachers, the laboratory management system should include an online evaluation for the quiz/viva-voce, checking experimental data, grading of submitted laboratory reports and feedback for the students.**

In this paper, we describe the design and prototype implementation of an online laboratory management system (for use with shared hardware-based remote laboratory resources) which may be employed for running internet-based online laboratory courses for geographically dispersed Institutions.

Keywords - *Online experimentation, online laboratory, remote control, e-learning*

I. Introduction

E-LEARNING has been a topic of growing interest in recent years. It is a group effort, where content authors (educators), instructional designers, multimedia technicians, database administrators, and people from other areas of expertise come together to serve the community of learners.

Online Laboratory is a subgroup of these e-learning systems where the learner or the user interacts and operates the hardware from a remote location. Online laboratories must be operated with a laboratory management system (LMS) that make sure that the experiments being performed generate the desired results and also serve for the other requirements of each individual user.

The primary objective of the LMS is to manage the learners, keeping track of their progress and performance across various stages and types of training activities. The LMS should be able to manage and allocate resources such as registration, schedule instructor availability, serve instructional material fulfillment, online learning delivery, and authoring system. It should also provide an infrastructure that can be used to create, modify, and manage contents for a wide range of learning environment to satisfy the needs of rapidly changing laboratory education requirements.

The LMS also need to provide a scheduling system that makes sure that each user or a group can use the hardware without overlapping or disturbing the running of experiments of others. Also, there is a need for creating online laboratory facilities across multiple institutions through shared resources. By sharing resources (i.e., remote laboratories and corresponding curricula online) the high costs associated can be reduced. Currently, running an online measurement-based laboratory is an open challenge. Remote control of instruments and the execution of real experiments via the Internet are topics of interest for many researchers.

The LMS should also be able to save the experiment data, retrieve and evaluate and compare data on learner scores, navigation habits and use them to provide content managers (educators) the crucial information on the effectiveness of the content, if combined with specific instructional strategies, delivery technologies, and learner preferences. One such laboratory management system, NETLab, is being introduced in this paper. The system is in use in laboratory education. With LabVIEW for instrument control, the NETLab is being used for teaching microelectronic devices concepts in the courses EC29003 (Semiconductor Devices Laboratory) and EC29004 (VLSI Engineering Laboratory) at the Indian Institute of Technology, Kharagpur.

There have been a number of different approaches [1-4] proposed to develop laboratory management tools for online laboratories. Management of an online laboratory system requires at least the followings:

- Experiment scheduling
- Delivery of assignments
- Performing the remote experiment
- Publishing of the laboratory report
- Interactive session: students and teacher
- Evaluation (viva-voce) and assessment

Web Services are being proposed for distributed applications and have great potential for building online laboratory management system [5]. It needs to manage the local resources on the local area network (LAN) and the remote resources connected by the Internet. Among the other resources to be managed are the computational resources which are managed using Grid Service techniques. Experimental instruments are managed by Web Services. However, based on rather a simpler configuration, our proposed online remote laboratory is based on client-server architecture and uses off-the-shelf middleware for communication. Products from companies, such as National Instruments (for controlling) and Agilent (for measurement instrumentation) are chosen. Windows™ is the operating system for these instruments and the client side also needs to install proper software to operate the remote instruments.

II. SYSTEM DESIGN

The NETLab uses the following components:

i. Java server pages and Java servlets as the means to design web pages.
ii. The back end consists of Oracle 10g. The Oracle Database (commonly referred to as Oracle RDBMS or simply Oracle) is a relational database management system (RDBMS) produced and marketed by Oracle Corporation.
iii. This system uses JDBC connection to build a connection between the java interface and the database.
iv. The Sun GlassFish Enterprise Server v2.1 is used as the application server that generates the web pages according to the user inputs. The Sun GlassFish Enterprise Server is a comprehensive support offering for GlassFish, the leading open-source and open community platform for building and deploying next generation applications and services.
v. The front end is a computer with a JavaScript-enabled browser such as Internet explorer or Mozilla Firefox. JavaScript is an easy-to-use client side scripting language which loosely follows the Java syntax but its design principles are derived from the self-programming language. Currently all the major web browsers (Internet Explorer on Windows, Safari on Mac, Opera, all the Mozilla based browsers) support JavaScript. This assures that the application is OS and browser independent.

The NETLab system has a special interface that connects to the hardware through GPIB card. The overall system configuration is shown in Figure 1.

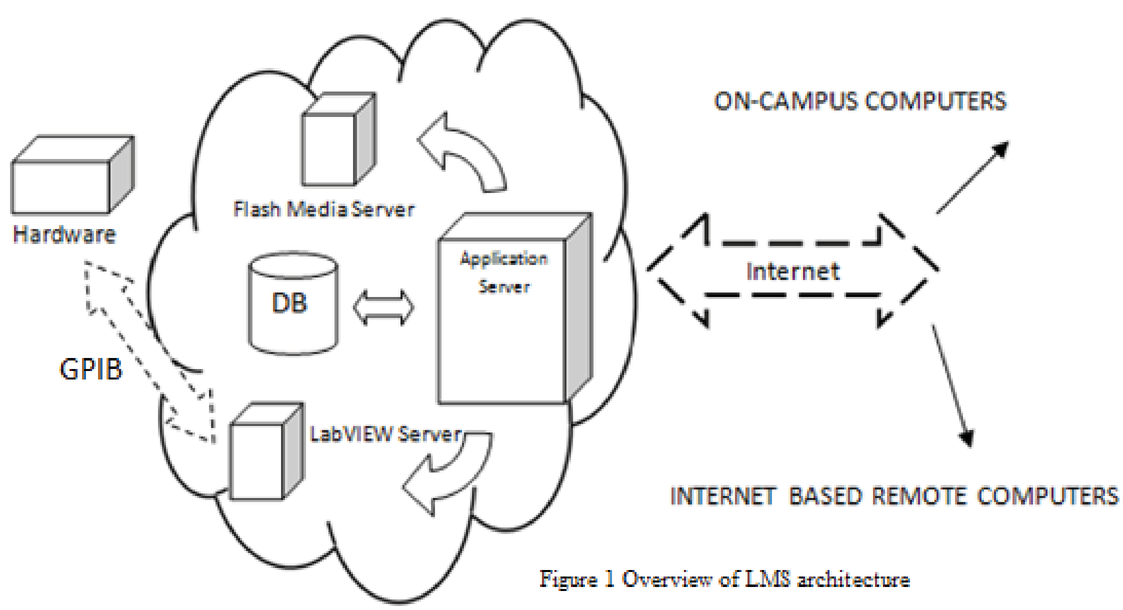

Figure 1 Overview of LMS architecture

These interfaces are built using the web development tool of NI LabVIEW 2009. The devices are connected and controlled by using the interface and their corresponding drivers.

Each user (student) need to register to get a username and a password (Figure 2). The students profile is also stored in the database. The user has to login and select a particular experiment and proceed. Each experiment has the following features: a laboratory manual, description of the experiment, experimental procedure, etc. As the system works in a batch mode, it distributes the time in slots and each user has to select and choose a particular time slot of his choice for performing the experiment. However, the experiment manuals and other functions are available at all times. Once the student logs on to the system, he has an access to the laboratory and gains full control of the laboratory hardware (experimental setup). The user can adjust experimental parameters or submit new commands in real time. When the allotted time for the experiment is over, the link is broken with a warning. However, the student gets a number of chances to book and perform the experiment till completion. This is done to optimize the use of the laboratory resources so that a large number of students can access the online laboratory.

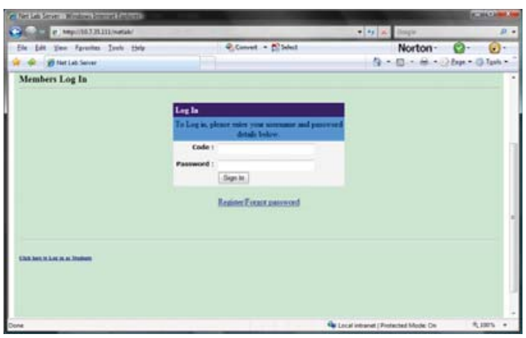

Figure 2 - Log In page.

After performing the experiment the student need to store the data, plot graphs and analyze the data for the preparation of the laboratory report. Then the student can upload the laboratory report and need to take part in a viva session for evaluation purposes. However, if a student cannot complete the above tasks in one session, he may perform the experiment again.

III. ON-LINE SCHEDULING SYSTEM FOR LABORATORY EXPERIMENTS

Online line laboratory consists of several experiments which the students have to perform in a semester. In the proposed LMS, only one student can choose an experiment at a time from the list of available experiments in the module. A student first needs to find an available time slot and then book the time for the experiment (Figure 3). As the time taken for different experiments are different, a typical runtime may be selected by the instructor and the pre-estimated runtime is provided for the particular experiment. The scheduling system for online experiments described here assumes that the students would be able to finish their experiments in the time slot provided, just like they would do in an on-site laboratory.

In NETLab each experiment is associated a given time slot which the administrator thinks is enough for running the experiment, keeping in view the speed of Internet and other network elements. Pre-experiment learning using laboratory manuals etc. and/or post-experiment data analyses etc. are not included in the experiment time slot for the optimized use of the hardware resources.

The workflow may be summarized as follows:

- The learner selects an experiment
- Then the learner opens the scheduling Web page link in the experiment page

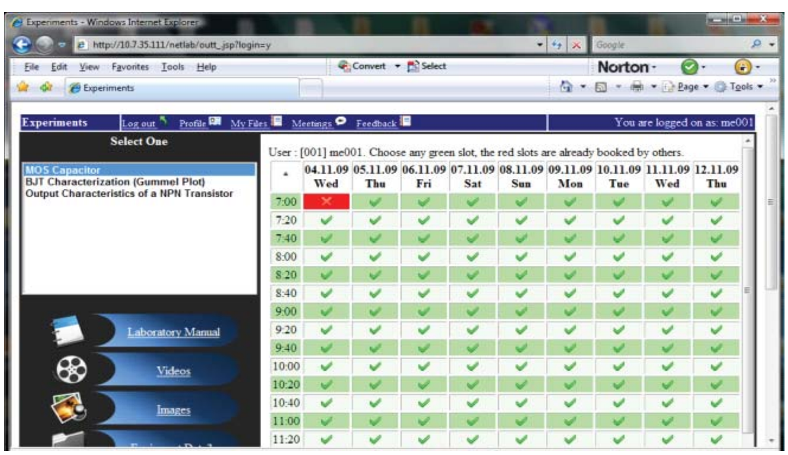

Figure 3 - Booking System.

- The system displays the scheduling interface for the next 15 days
- The system displays the available time slots for the selected experiment in green color and unavailable slots in red
- The learner then selects the date for carrying out the experiment in the scheduling interface
- The learner selects a desired time slot from the available time slots and submits the request
- The system saves the learner schedule information and updates the scheduling database
- The system displays a confirmation of the schedule to the learner

IV. LEARNING MANAGEMENT FUNCTIONS

Learning management function modules include authoring tools to generate laboratory tutorials, quiz, and data analyses. An embedded student management system manages the enrollment, marks/grades and progresses of students, and multiple collaboration tools, such as discussion forum, and chat rooms for students to communicate and work.

In the current version of the LMS the functions included are:

- Manuals (pre-laboratory and experiment) contain detailed information about the experiment (Figure 4). These are simple html pages that contain various type of information given in a usual on-site laboratory manual as well as the other detail needed for online interactions.

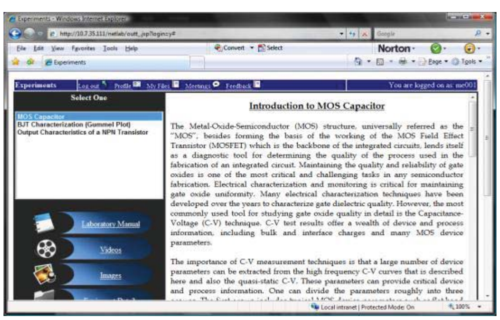

Figure 4 - Lab Manual.

- The video/image section contains videos and images about different aspects of the experiment (Figure 5). This helps the learners to have a clear concept about the real experiment would be like in a conventional in-campus laboratory. The video and image section is one of the most important parts of the LMS since there is little direct interaction between student and teacher and the actual experimental setup. The videos/images provide a vivid view of what the actual experiment would look like and build the confidence in the learner about he could do in an on-site laboratory.

Figure 5 - Video Gallery.

- Equipment details section that contains the information about the instruments used in a particular experiment (Figure 6). Every experiment requires a set of unique equipments and/or instruments. These equipments have unique control systems and also specifications. This section describes each of the instruments with both pictures and text which help the learners to be familiar with the necessary instruments. It is expected that the student will be able to perform the same experiment in a real laboratory without any difficulty.

Figure 6 - Equipment detail.

- Interactive Animation section includes animations that would simulate the setting up of the experiment (Figure 7). This is another very important aspect of the NETLab LMS where the learner follows a series of steps in form of an animation that helps the learner to understand the ways to setup the experiment. These animations are built using Adobe Flash CS4.

Figure 7 - Experimental setup (animation).

- Sections involving Question box and video chatting would provide ways to communicate with the instructor and also other students (Figure 8). This feature is very important for collaborative learning as needed in online laboratory education. The learner can use this feature to communicate online with the teacher and ask questions (in case of doubt) which teacher would respond to. In the LMS developed, provision has been made to display all the questions asked by the students and the answers provide by the instructor. Also, further provision has been made for a learner to request for a video conferencing with the teacher to discuss online on the experiment. During above scheduled video conferencing, other students can also join which would help in collaborative learning.

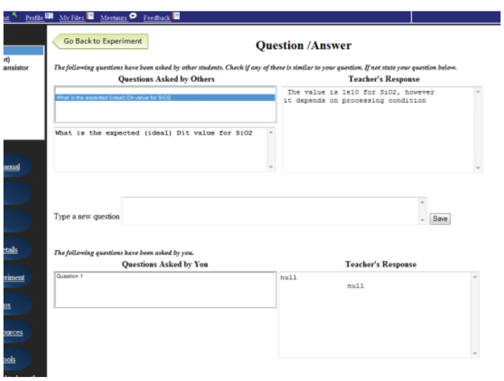

Figure 8 - Question/Answer (student feedback).

V. EVALUATION OF STUDENT PERFORMANCE

To aid teachers' online evaluation of student performance, provision has been made for keeping track of status at various stages of the experiment for each student and the evaluation is done. The process of evaluation is done in multiple steps as follows:

- Preliminary Quiz is conducted before the learner can access the actual experiment page (Figure 9). This is done online and consists of some random True/False type questions from the theory, manuals on the experiment and the instruments used. Only after checking that the learner has obtained 50% or above marks, the student is allowed to book the experiment time slot. This is done to optimize the use of the instruments and to make sure the students know about the instruments and also the experiment.

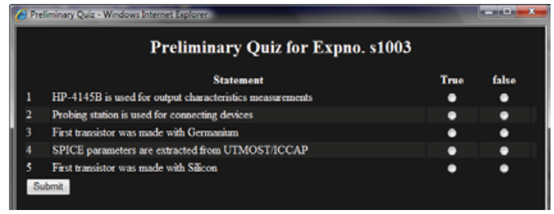

Figure 9 - Preliminary Quiz.

- After the Experiment has been performed successfully, the learner needs to save and plot graph etc., analyze data, interpret the results, and extract parameters, if applicable. Provision has also been made for online analysis using tools which may be supplied by the instructor. Once this is done, the student is now in a position to prepare the laboratory report for uploading (Figure 10). The laboratory report must contain the detail on the experiment done as well as the data obtained and results and discussions. However, the report file needs to be saved in a particular format. Once the laboratory report is submitted by a student, it is accessible only to the instructor who may check it manually and grade the student. If necessary, the instructor may send feedback on the experiment to the student and ask for resubmission. Laboratory reports of students are not accessible to others.

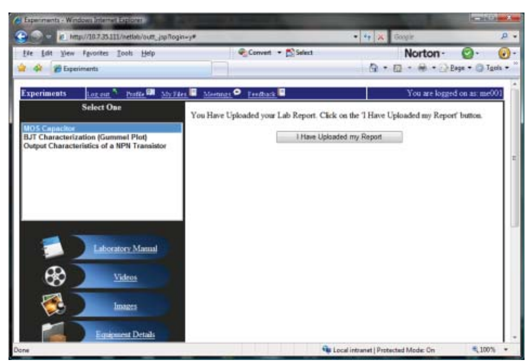

Figure 10 - Laboratory report.

- After submission of the laboratory report, the student needs take part in the online viva-voce examination (Figure 11). The viva-voce session requires answering of different types of questions set (already made available in the data base by the instructor). Both the viva-voce session and laboratory report are then graded and a final grade for the student is prepared and uploaded so that the student knows his grade.

Figure 11 - Viva Voce.

VI. EXPERIMENTAL SETUP

When students log on (during booked time) they can access the experiment pages. The html pages contains embedded object which are basically created using the LabVIEW Web development tool [5]. The html files are hosted and distributed by an in-built LabVIEW web Server. The interface in derived from the VI files created in the LabVIEW 2009. During the experiment, the students take over the control of all the equipments and can set the necessary experiment conditions from the user terminal (Figure 12). The measurements are made and the data are transferred to the client's PC. The html pages also contain learner information and display the time left during experimentation. Once this time is over a JavaScript function simply displays a warning alert and then closes the window. The student needs to place at least one screenshot of the html page in the laboratory report to prove that the experiment was done by him.

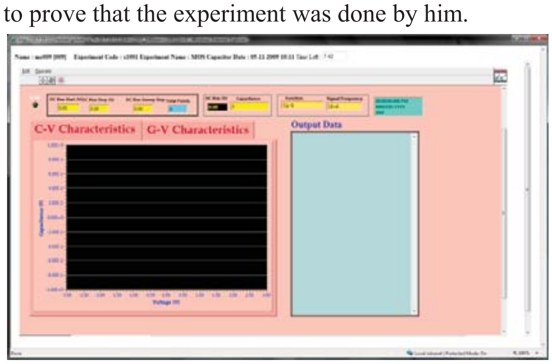

Figure 12 - Labview interface.

VII. ADMINISTRATION

The NETLab LMS contain an administrator section for the teachers and administrator to keep control and track of what is going on in the system (Logbook). The teachers can easily check the students' entry/exit records for information for future reference. The administrator can create new experiments by entering information about the experiments such as manuals, videos, images, animations etc. to update the laboratory module. Teachers are permitted to check the student's laboratory report and answer to the student questionnaire raised in the question box. The Logbook section displays information about the student progress, the grade obtained and the time and period when the students performed the experiment.

Following are the results of the students' and instructors activity profile (usage statistics) and opinion about NETLab as a learning tool. This study is based on a student population of about 40 in EC29003 Devices laboratory for the period January-April 2009. All the students used the same website http://203.110.240.33/netlab, which has the functionality such as choice of experiment, experimental procedure, laboratory manual, pre-laboratory theory etc. Interactive session with teachers and students, as well as an inquiry/feedback, formed the basis for the evaluation. Evaluation procedures consist of several criteria, such as, Very Poor (VP), Poor (P), Fair (F), Good (G) and Very Good (VG) as measures. Student Feedback Form were used regularly which helped in receiving online feedback regarding their laboratory exercises.

Laboratory Assessment Tools were used for evaluating the effectiveness of the Laboratory experiments in terms of pedagogical benefits, resource utilization and cost effectiveness on a regular basis. Analytical Tools were provided in each experiment to help in performing various analyses on the data collected during experiment. Following typical parameters were used for evaluation:

- Freedom of Access
- User Friendliness
- Unmanned Assistance
- Assessment Support
- Experiment's Effectiveness in Learning
- Freedom of Creative Experimentation
- Ease of Modifying experiment
- Skill Developed
- Operational Control
- Availability of Analytical Tools
- Performance Effectiveness

Survey for Devices Laboratory EC29003 was carried out at the end of the semester during Spring Semester 2009.The survey consisted of ten questions and its main objective was to measure the acceptance, usability and usefulness of the NETLab developed at IIT Kharagpur. The evaluation system has been chosen as: marks 6 and 8 are “very good”, 1 and 2 “poor” and 3 and 5 “good”. With this evaluation system, each student’s answers were evaluated. Further, the information obtained from the Logbook may be used for the evaluation of the LMS itself, for example, the weekly utilization information of the laboratory module is shown in Figure 13.

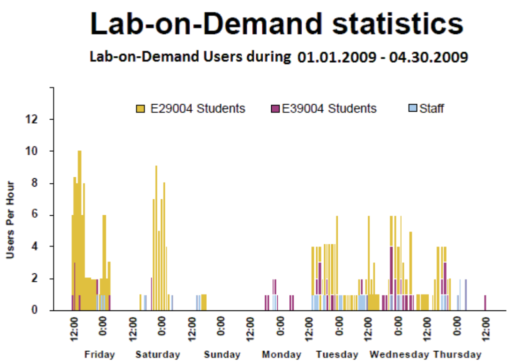

Figure 13 - Usage of NETLab showing preference in the weekend.

Table 1 - Survey response.

Question	Score
1. Has NETLab helped you with the Experiment?	8
2. Do you think it is a good idea to have an Internet remote laboratory?	7
3. Is it easy to use?	6
4. Did you feel at comfortable in changing the inputs?	7
5. Was the allotted time for experiment was sufficient?	8
6. What do you think about the inputs/outputs (in webpage) implemented?	6
7. Being not able to see the equipment, how you felt yourself to be in the instrument control?	5
8. What is your overall satisfaction with NETLab?	8
9. Have you ever faced with the server down?	1
10. Were the other available resources useful?	7

Table 1 shows that the opinion of the students and it is remarkable that the score of the questions related to suitability (Q1), time of experiment (Q5) and satisfaction (Q8) are high showing the effectiveness of online remote laboratory.

VIII. CONCLUSIONS

NETLab (Online Laboratory Management System) has been designed and installed for use in the undergraduate and postgraduate “Microelectronics and VLSI engineering Laboratory” at the Indian Institute of Technology (IIT), Kharagpur, India. The system described here currently uses manual teachers’ evaluation procedure. Attempts are underway to provide fully automatic online evaluation for both the laboratory reports and viva-voce examination.

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Reconfigurable weblabs based on the IEEE1451 Std.

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Abstract— ***Technology plays a double role in Education: it can act as a facilitator in the teaching/learning process and it can be the very subject of that process in Science & Engineering courses. This is especially true when students perform laboratory activities where they interact with equipment and objects under experimentation. In this context, technology can also play a facilitator role if it allows students to perform experiments in a remote fashion, through the Internet, in a so-called weblab or remote laboratory. No doubt, the Internet has been revolutionizing the educational process in many aspects, and it can be stated that remote laboratories are just an angle of that on-going revolution. As any other educational tool or resource, the i) pedagogical approach and the ii) technology used in the development of a remote laboratory can dictate its general success or its ephemeral existence. By pedagogical approach we consider the way remote experiments address the process by which students acquire experimental skills and link experimental results to theoretical concepts. In respect to technology, we discuss different specification and implementation alternatives, to show the case where the adoption of a family of standards would positively contribute to a larger acceptance and utilization of remote laboratories, and also to a wider collaboration in their development.***

Keywords: E-learning, Remote experimentation, Remote laboratories, Reconfigurable weblabs, IEEE 1451.0 Std..

I. INTRODUCTION

The process of learning through technology is contributing to social changes. The size of available information for consulting has been imposing some pressure towards people, since they are now obliged to be constantly updated to avoid cultural and social isolation from the remaining society. Higher education has a big influence over this trend and must encompass current technological changes, so it may provide all means to satisfy people requirements by creating new educational resources. This has been happening since the 80's with the appearance of PCs and interactive CDs with multimedia contents. More recently, in current digital era, information circulates freely through internet and everyone have access to it, using PCs or mobile devices. This has been improving the learning process with the several educational tools developed, and technology is now viewed as fundamental to complement the traditional classroom. While at the beginning educational tools only covered traditional lectures, today the huge advances of internet services (larger bandwidth, many communication tools, etc.), have being promoting the adoption of learning technologies in the Sciences and Engineering (S&E) courses, namely in the laboratorial work, through the so-called weblabs.

This paper starts with some considerations about the problems and the added value that technologies are bringing to education. Focusing in the S&E courses, section III presents the relevance of experimental work, and section IV compares different laboratory environments. Section V describes the emergence and proliferation of weblabs, and the problems now faced by this educational technology. In this same section some infrastructural problems are pointed out and a reconfigurable weblab infrastructure, based on the IEEE1451 Std., is proposed.

II. TECHNOLOGY IN EDUCATION

In our present era, technology has been changing the way knowledge is acquired, facilitating students' access to information by lowering barriers once difficult to overcome due to social and economical restrictions. However, there are too many resources available, like books, journals, etc. that may contribute to information fragmentation, leading to an incoherent learning. This requires sense making to interpret, organize and link information to make it coherence. A critical attitude towards the learning process is fundamental, since not all the disseminated information is trustful (some are from specific entities, with credits in a specific area, and others are from individuals that can disseminate wrong information). A constructivist attitude is required, as students are building their knowledge based on information created by others.

Today skills are acquired not only inside a classroom but also outside, which requires an educational role based on two principles: i) traditional and ii) emergent. While traditional principles focus on pursuing ideals for influencing education to transform society with equality and democracy for all, following well defined theories and learning methods; emergent principles must defend a reaction of education to the technological trends, by adjusting theories and learning methods to influence students. This will be achieved by understanding students' needs and embracing their tools and skills, so it becomes possible to speak their languages and motivating them to learn, as already defended by theorists like Maslow or Herzberg's [1][2]. It is fundamental to look at education as a global process that may be improved through technologies. Spite the *Social Development Theory* presented by Vygotsky [3] focused on connections between people and the socio-cultural context in which they act and interact by sharing experiences, it does not pay attention to a social context characterized by the existence of social networks, which provides even more interactions between people and internet-based resources. Here, the *Communities of Practice* (CoP) described by Jean Lave and Etienne Wenger in 1991 [4] is still actual, because technologies facilitate more interaction, allowing students' collaboration by sharing ideas, strategies and practical experiences, through a global network. They are able to acquire skills more easily than ever, and influencing their attitude towards learning. This has been promoting changes in higher education, by shifting its focus from knowing, described by epistemology as a conjunction of truths and believes, to being, described by ontology as capacities and processes that allow a student to get and easily understand new information. Students' curricula should emphasize qualities and attributes for learning, rather than particular knowledge elements. The much information available requires students' capabilities to learn by their own, so know-what can be supplemented by know-where information can be found.

The today's common *Network Learning* concept defines a process of developing and maintaining connections with people and information to support one another's learning. As described by Siemens and Tittenberger [5] this network comprehends several nodes divided in three levels: i) neural - based on neuroscience studies where nodes are neurons; ii) conceptual - related to cognition, the nodes are seen as ideas or collections of ideas; and iii) external/social - supported by new web technologies that allow interconnecting students by social networks, blogs, wikis, forums, etc.. At this level, a node is a person or an information resource. These led to the appearance of a new paradigm named *Connectivism* [6] that classifies each piece of information or student/teacher as a node that interconnected with others, understood and classified as relevant/irrelevant and trusty/untrusty will create knowledge, promoting a coherent learning, as illustrated in figure 1.

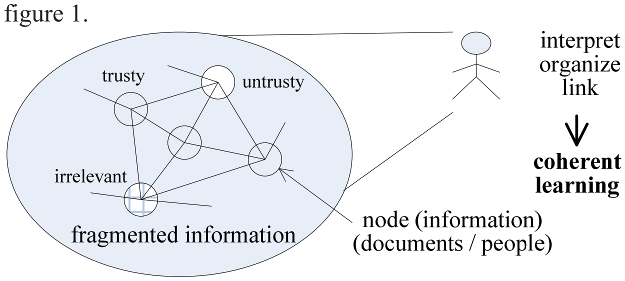

Figure 1. Coherent learning achieved through fragmented information.

As all nodes are interconnected in a network, each may influence all the knowledge already acquired. A resistance for learning and the *Cognitive Dissonance* [7], which describes a discomfort feeling when new information appears and tends to change previous beliefs, are no longer relevant, since information is constantly changing and students must be well prepared for changing their ideas supported by a critical attitude. However, the diversity of technological solutions and the amount of information available, namely in the internet, may lead to confusion in students' research, requiring a critical attitude and teacher's guidance through the whole learning process.

As presented in figure 2, the educational landscape has been changing since the 80's. If at the beginning the face-to-face instruction was the most preeminent method in education, the evolution of computers and the appearance of the internet, and its associated services and tools, incentivized students to learn (learning) instead of simple receiving information (instruction). Computers provided the use of simulations, interactive courses with multimedia contents, and other advanced resources, but the internet appearance brought the emergence of the e-learning concept providing the remote access to multimedia resources, the use of learning tools, the collaborative work using synchronous (e.g. videoconference) or asynchronous (e.g. e-mail) communication tools, etc.. Today, some of these tools are accessed through mobile devices (mobile phones, smart phones and PDAs) which provide the foundations of the m-learning concept. More recently appeared the web 2.0 allowing students and teachers to interact as a group (geographically dispersed) with web contents using blogs, wikis, etc., which allow to create and disseminate even more educational contents.

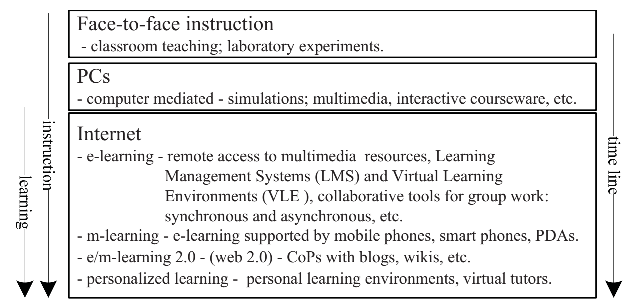

Figure 2. Educational landscape since the 80's.

Since the educational context is becoming more personalized, the spread of different tools and contents in the internet may create some confusion in a student's mind. To overcome this aspect, *Personal Learning Environments* (PLE) are appearing to support students' creation of their own environment (supported by a set of tools) so they can control and manage their own learning process.

Applying technology in educational contexts promotes changes in the traditional in-classroom learning that can be i) extended, ii) partly replaced, or iii) entirely replaced by its application. Extending the classroom with technology resources is very common and has been applied through computers and multimedia resources for fostering what students learn in the traditional classroom. More recently, solutions ii) and iii) have been spreading in the educational context, since internet and its associated services fulfill basic requirements encountered in traditional classrooms:

- dissemination - teachers/students can use websites and digital presentations with images and animations to disseminate their lectures/works, eventually supported by *Virtual Learning Environments* (VLEs), *Learning Management Systems* (LMS) and podcasts;

- discussion - there are several communication tools available; from synchronous (chats, videoconference, etc.) to asynchronous (e-mail, discussion forums, blogs, etc.), all contributing for the required teacher-student and/or student-student interaction that facilitates cooperative and group work activities;
- discovery - the internet provides access to several resources, allowing students and teachers to seek new information and tools;
- laboratory work - using the so-called remote experimentation concept, students/teachers may run or demonstrate real laboratory activities through the internet;
- assessment - while self assessment can be made through current VLEs (which comprehend several tools), traditional classroom assessment can use synchronous communication tools, so teachers can control students' assessments.

In spite of the basic requirements fulfilled by technology, it is important to be aware of the sense of isolation that students may have if the in-classroom learning is entirely replaced by technology. Some literature points this aspect as a drawback to entirely adopt technology in educational contexts, because this may lead to students' frustration, decreasing their motivation. Moreover, currently educational trends in higher education defend the adoption of the *Problem Based Learning* (PBL) theory where students' tasks focus on solving specific problems proposed by teachers. The teachers' task is restricted to supervision and guidance of students, so they can solve problems by researching and making decisions by their own, which may cause some isolation. In this context, adopting a methodology partially supported by in-classroom learning and partially using online resources will facilitate the adoption of the PBL theory overcoming the isolation drawback. As defended by the *Blended Learning* concept, nowadays the learning processes tend to be hybrid or mixed focusing on technologies tendencies to partially replace the in-classroom learning, providing students and teachers with more resources to improve education. This aspect is being applied in S&E courses, where the required experimental work is supported by educational tools.

III. Experimental Work

To apply the PBL theory in higher education, technology resources, like internet and its associated services, are fundamental, since they facilitate students' research, giving them the opportunity to learn by their own. It is important to understand how the new educational tools can be adopted in the particular case of S&E courses. As illustrated in figure 3, there are two important components for achieving learning: i) theoretical and ii) practical. While theoretical concerns transition of knowledge using the traditional pedagogical contents supported by documents, images and animations, describing specific theories; the practical component require students to be actively involved in the manipulation of variables and objects by doing experimental (or laboratory) work, researching, participating in group activities so they can understand, build, and verify theoretical concepts. In fact these are just some of the experimental skills that students should acquire in the laboratory environment, as reported by Feisel and Rosa in [8], which describes the role of the laboratory in engineering education.

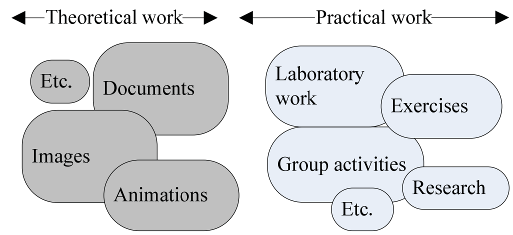

Figure 3. Theoretical and practical work.

Both theoretical and practical components are fundamental in every S&E course, since almost every theory concerns practical issues, and vice-versa. Besides, applying PBL theory requires well designed courses dividing practical work into: i) resolution of exercises, ii) laboratory work (either traditional or simulated), iii) research, and, iv) group activities, among others. The results obtained through these activities, for acquiring a specific skill, will contribute for an autonomous learning process, since students are able to compare the results obtained in each activity, gathering variables to analyze a specific phenomenon. Supported by results, students can justify the validity of a specific problem, enriching the learned theories. If those variables do not correspond to the expectations provided by theories, students are invited to reformulate them. The relation between theoretical and practical work can be viewed as a cycle with two dependent components that, if applied, will promote more consistence, autonomy and responsibility in the learning process. Moreover, motivation increases, since students have the possibility to interact with the described phenomena in a learning-by-doing scenario. The teacher should guide students to choose specific literature and tools so they can satisfy both theoretical and practical components.

Each activity has differences that must be analyzed in terms of their importance in S&E courses. While exercise solving and/or simulations provide results returned by theoretical models, i.e. students do not interact with real equipment; the traditional laboratory work gives students the possibility to work with real equipment where the results obtained can not be classified as non-real like in simulations or exercises.

Besides the importance of laboratory work for achieving good learning results, it is also fundamental to understand how students can be motivated to learn in S&E courses. Reporting the educational theorist Kolb [9], students have four different styles for perceiving and processing new information: feeling and thinking (perception), and watching and doing (processing). The analysis made in [10] based on the preferred learning styles of 49 S&E students indicates that most preferred doing and thinking (which are typically of laboratory work) rather than feeling and watching, as illustrated in figure 4. Moreover, the results obtained from a questionnaire made to those same students indicated laboratory work as the component that allows them to learn better, rather than lectures, reading or homework exercises.

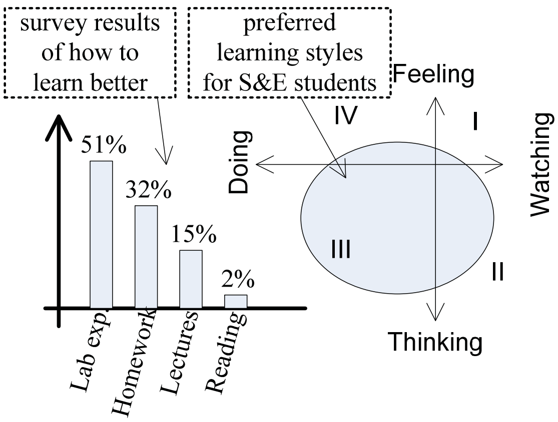

Figure 4. Survey results and preferred learning styles for learning in E&S courses (reported from [10]).

Supported by this analysis and reporting the research made by Ma and Nickerson [11], laboratory work is classified as one of the most important components of S&E courses, since students are able to acquire experimental skills which are fundamental in a practice oriented field such as engineering. This has been motivating the analysis of how can laboratory work be enhanced through technology, namely by providing different laboratory environments.

IV. Laboratory Environments

The proliferation of several technologies and services supported by internet allow creating several laboratory environments so students can conduct laboratory activities. As illustrated in figure 5, it is possible today to classify laboratories according to the access (remote or local) and resource (real or virtual) types, each one presenting specific characteristics:

- Traditional laboratories - represent the common laboratory already available before the appearance of the internet and associated services. In these laboratories students have contact with several instruments/modules (I&M) associated with an experiment and may or not may collect data through a computer. Student must physically be in the laboratory to conduct a specific experiment.
- Remote laboratories - represent a remote access to real experiments, using an internet connection. Students interact with real equipment like in traditional laboratories, however they are not required to be in the laboratory, since they can access it through a simple device (mobile or not). All actions should be carried out using the accessing device.
- Hybrid laboratories - these laboratory environments comprehend both kind of accesses and resources. Considering a remote access, students may use a simple device to access an experiment through the internet where, during the interaction with the I&M associated with the experiment, some parts can be real and others can be simulated by software. If the access is local, the laboratory comprehends some real I&M able to control locally like in traditional laboratories, but it has some simulated using a computer. Both are interconnected in the laboratory. This environment is still uncommon but it is important to consider it in occasions when the I&M are expensive and/or unavailable, and in situations where experimental variables are impossible to visualize (e.g. visualization of magnetic field lines) [12][13]. By using these hybrid laboratories, students may collect data using their accessing devices or the computer that simulates a specific I&M.
- Virtual laboratories - all the I&M are simulated using a computer. Although this solution comprehends the simulation of an experimental work, the interface provided for students must give them the sense that they are controlling real equipment. The access type can be either local or remote, as students can control a simulated laboratory by installing specific software on their devices or they can access a virtual laboratory through the internet. All data can be collected using the accessing device of each student.

The choice for a specific laboratory environment depends on educational contexts, comprehending the institutions, course requirements, and the type of students/teachers that will use the laboratory. Hence, a detailed analysis based in some parameters and costs is required.

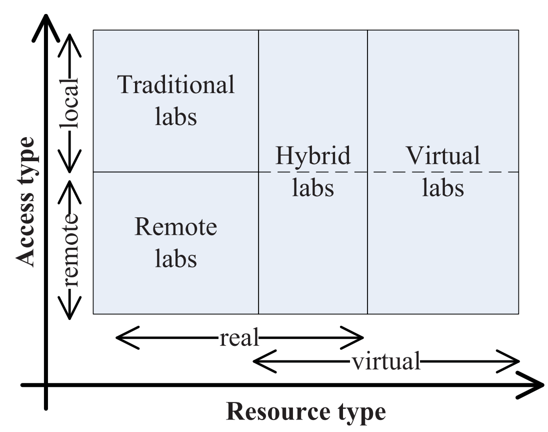

Figure 5. Types of laboratory enviroments.

The following parameters should be considered:

- Availability - a specific experiment should be available at all time. Since typically there is a lack of infrastructures and I&M to satisfy all students enrolled in a specific course, it is usual to schedule accesses, so experiments can be shared through time slots;

- Reliability - it is fundamental to analyze theoretical approaches using reliable data retrieved from a specific experience, so theoretical approaches can be proved or reformulated. Moreover, reliability also concerns the stability of the implemented laboratory, namely if it is able to work correctly during long periods of time without setup requirements or maintenance;
- Flexibility - the ideal laboratory environment should provide a platform (software and/or hardware) able to accommodate every kind of experiments, without changes;
- Reusability - a specific laboratory or experiment should be able of been used more than once, and the I&M should be able to be shared with other experiments available in the same institution.
- Motivation - the provided experiments must be well designed to motivate students' adoption. The setup and reconfigurability must be easily defined by the student (preferably without teacher or technician assistance) and the interactivity and realism should be high, so students can have real time access to equipments and data;
- Group activities - the ability to share experiences and ideas during laboratory work is fundamental to achieve good learning results. Hence, it is important to enable the conduction of experiments in groups, by allowing student-student and teacher-student communications. In an institutional level, sharing resources and I&M will improve laboratory work quality, since each institution has its specific skills in different areas enabling more quality in the provided experiences. The sense of isolation and solitude, pointed as a drawback for learning, must be overcome by this interaction.

Costs can be divided into two groups: infrastructure /equipment, and those involving actors (students/teachers + technicians):

- Infrastructure/equipment - if the local access is adopted, a laboratory experiment requires a physical space to accommodate both actors and equipment. If the remote access is adopted, an experiment does not require a large place for accommodation, since actors do not need to be in the laboratory place. Moreover, an analysis of the available equipment versus the cost of each unit together with the course requirements, in terms of how many laboratory experiments must be created, should be well analyzed. If the equipment is expensive and it is required several experiments, probably creating only one experiment able to share by several students is the best solution;
- Actors - the setup and the maintenance of a specific laboratory require at least one technician paid by the institution. Although not directly related with the institution, if the local access type is adopted rather than a remote access, students may have associated dislocation costs.

Reporting to all these parameters, table 1 provides a comparison among laboratory environments. Each parameter was classified following our acquired experience in previous international projects (PEARL [14] or ReXNet [15]) and has a mark from 0 (less favorable) to 5 (more favorable). They were analyzed focusing the use of software or hardware and on network requirements to access a specific experiment. The particular case of motivation was classified based on the adoption of technology and on the use of real or virtual I&M (i.e. higher motivation if students are using technology and real equipment).

TABLE I. COMPARISON AMONG LABORATORY ENVIRONMENTS

	Parameters						Costs		Sum	Weighted Sum
	Availability	Reliability	Flexibility	Reusability	Motivation	Group activities	Infrastructures /equipment	Actors + technician		
Traditional	2	5	3	3	4	5	2	2	26	**36**
Remote	3	4	3	4	5	4	4	5	**32**	**40**
Hybrid (remote)	3	2	4	4	3	4	3	5	28	32
Hybrid (local)	4	3	4	4	3	4	3	2	27	33
Virtual (remote)	4	1	5	5	2	5	5	5	**32**	34
Virtual (local)	5	2	4	4	2	5	5	2	29	33

Summing all lines, we may observe that virtual (remote) and remote laboratories environments have the highest mark (32), and probably should be the preferred choices to conduct laboratory work. However, from our experience, reliable results should be the most important parameter of analysis. Hence, by giving at least 3 times more importance to the reliability factor, the results will change, placing remote and traditional laboratories on top, with 40 and 36, respectively. This is inline with several theories that defend laboratory work environments should be provided by both solutions, placing remote laboratories as a complement for traditional laboratories, because both return reliable results.

While traditional laboratory environments are applied in education since the beginning, today, with the internet proliferation and the associated services, remote laboratory environments are becoming widely adopted. So, the use of these environments conduct to the appearance of weblabs that are becoming widely adopted in S&E courses.

V. WEBLABS

Weblabs are an important resource for complementing e-learning environments, as they provide the possibility to run remote experiments. Typically, weblabs are supported by VLE /LMS (e.g. Moodle) that provide all the pedagogical contents and resources that partly replace the traditional in-classroom activities. Remote experiments are accessible through simple

2D interfaces, and more recently, the use of 3D interfaces are being considered by the research community, since they provide an immersive environment where students can interact with the entire laboratory, approaching remote to traditional laboratory environments and increasing students' interest and motivation for laboratory work. Additionally, the recent technological evolution, which causes several instruments to be factory-equipped with Ethernet physical interfaces, is also promoting weblabs as important resources to improve laboratory work activities. This is proved by the increasing number of weblabs implemented at universities and schools [16] that give an added value to courses that usually only provide traditional laboratories, and to others courses that, due to a lack of resources (economical and/or technical), do not provide any laboratory work. This will facilitate changing the curriculum courses, giving students, spite of their social and economical conditions, access to real experiments and equipment, some expensive and others unavailable. There are no time constraints since students become more autonomous for conducting and repeating experiments at their own pace and they promote collaboration among different cultures and enable more "learn-by-doing", increasing students' motivation [17]. However, the implementation of weblab infrastructures comprehends some problems, which, in our view, may be overcome by adding reconfigurable capabilities to them.

A. *Weblabs' problems and new reconfigurable weblabs*

Spite of the large variety of weblabs available today, a large majority is focused in engineering courses [11][18][19][20] mainly because technical skills are required to create a weblab infrastructure. Moreover, each infrastructure is typically developed following specific and distinct technical implementations, with several hardware and software architectures that use different programming languages to remotely control the equipment [16][21][22]. The lack of a standard solution is hampering the wide-spreading of weblabs since it creates some problems:

- it does not promote large collaboration among institutions, because it is difficult to reuse and interface different instruments/modules used by a specific experiment;
- some institutions do not develop weblabs for supporting their courses, because they lack the required technical skills;
- costs may become high, since creating a weblab infrastructure requires a PC and associated software, together with several instruments;
- an architecture based on a single PC, poses constraints for running different experiments, and the required software layers usually create actualization problems due to non-compatibility issues between versions.

To overcome these problems, the use of reconfigurable weblabs based on boards with *Field Programmable Gate Arrays* (FPGA) that support a wide range of peripherals (A/D and D/A converters, interface ports, etc.) is a good solution [23], since they allow the accommodation of several I&M inside their memory blocks rather than using several independent instruments and a PC commonly adopted by traditional weblabs, as illustrated in figure 6. Furthermore, developing those I&M with open standard hardware description languages (VHDL/Verilog) and following a structure and an interface also defined by a standard, such as the IEEE 1451.0 Std., is a step in the direction of sharing and reusing the infrastructures and the I&M on other experiences and by other institutions. The IEEE 1451.0 Std. is a valid option because it defines a set of open, common, network-independent communication interfaces [24].

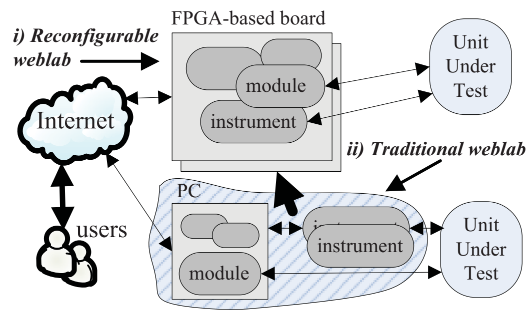

Figure 6. Traditional vs Reconfigurable weblabs architectures.

The added value of a solution based on standards for developing a weblab is large, but requires further analysis accounting for its educational requirements.

B. *Added value of reconfigurable weblabs*

Reconfigurable weblabs are more robust than traditional ones, since they do not use several software layers. A simple reconfiguration file using VHDL/Verilog description languages is sufficient to implement different infrastructures. Furthermore, there are no actualization problems, since this kind of languages are independent of any other software and FPGA manufacturer.

As reconfigurable weblabs are developed using FPGA-based boards and the IEEE 1451.0 Std., their implementation costs are lower than traditional weblabs that use PCs and several instruments, some with specific features eventually not necessary for a specific experiment. Reconfigurable weblabs adopt the same platform to accommodate several I&M able to be easily shared by several experiments that may (or may not) run in different institutions. Developing specific I&M using hardware description languages, allows easily sharing them by a simple download process from a specific web server to reconfigure the FPGA-based board, as illustrated in figure 7. To remotely control/monitor each I&M, a web interface should also be available. Hence, institutions may easily create their weblab without specific technical skills, since they become more reusable and flexible and the collaboration among institutions will increase, promoting the accomplishment of improved work group activities.

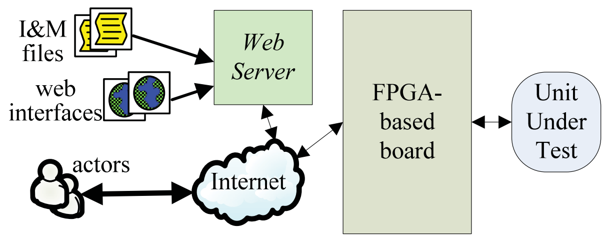

Figure 7. Distributed architecture proposed for FPGA-based weblabs.

Providing access to a laboratory requires scheduling, so several students may share a specific experiment. While in traditional laboratory environments scheduling classes is common, for weblabs two solutions are commonly applied: i) booking systems [25] and ii) running experiments in batch mode [26]. From an educational perspective, weblabs should provide students' feeling that they are interacting with real equipment as they do in a traditional laboratory environment. So, typically booking systems allows students to reserve a time slot so they can have total control over the weblab, like in the traditional laboratory. The adoption of reconfigurable weblabs provides an improvement to the traditional weblabs in this availability aspect, since FPGAs can be reconfigured with different I&M using two possible techniques: i) total reconfiguration or ii) partial (static/dynamic) reconfiguration. In total reconfiguration, using a new I&M requires reconfiguring all the FPGA by stopping its operation. This may be an uninteresting option for experiments using many I&M at the same time, since it requires stopping the weblab operation for changing them. Moreover, depending on the complexity of new I&M and on current FPGA configuration, this option typically requires more time to reconfigure the weblab than the second one [27]. Therefore, option ii) may be more appropriated if one needs many I&M to conduct an experiment, since it allows reconfiguring only part of the FPGA with one or more I&M, without changing the others inside. Two alternatives are available for partial reconfiguration: a) static or b) dynamic. Static reconfiguration requires stopping the FPGA, while in dynamic reconfiguration an experiment may keep running even if an I&M is changed. So, assuming one wants to change the reconfigurable weblab infrastructure when the logical space used inside the FPGA is totally occupied, only a fraction of it would be reconfigured, without affecting the rest of the FPGA. Eventually, that fraction could even be occupied by an I&M in operation in that instant.

Following on the FPGA reconfigurable capabilities, figure 8 presents a solution to solve typical scheduling problems encountered in traditional weblabs when 1 to N students wish to conduct 1 to N experiments. When there is only one experiment for a single student, there are no scheduling problems. However, when a single experiment is available and several students want to access it, a scheduling access is required. As previously referred, a typical solution to solve this situation is the adoption of a booking system where students can reserve time slots. At that slot time, no one else can access the experiment, which can decrease the availability of the weblab. By adopting the proposed reconfigurable weblab, the FPGA reconfiguration techniques will solve this problem, because it is possible to reconfigure several I&M, required for a specific experiment, in different FPGA's memory blocks. This allows student's transparent accesses to the experiments making them to believe that there are several available infrastructures. The only problem is the limited space available inside the FPGA that can also be solved using scheduling techniques or even the batch mode referred before. When one student wants to run different experiments, the reconfigurable infrastructure may provide different experiments running at the same time in different memory blocks or, in case of limited space, it is possible to change the experiments using one of the referred reconfiguration techniques. The most critical case appears if several students want to run different experiments. This requires the conjunction of both proposed solutions, i.e. the FPGA can be reconfigured with several experiments able to run at the same time for one specific student or, if several students want to run a specific experiment, it can be replicated in several memory blocks of the FPGA.

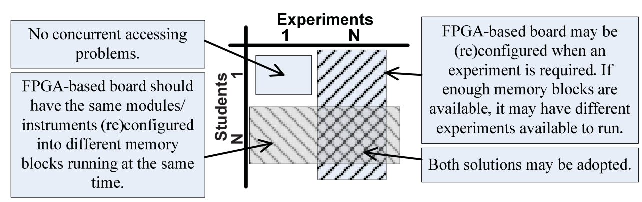

Figure 8. Solutions to run 1 to N experiments for 1 to N students on a single FPGA-based board.

C. *Security issues*

The reconfiguration capability provided by the proposed weblabs may cause some problems if students have access to the entire weblab infrastructure. It is fundamental to control the actions they are able to do, to avoid damaging the infrastructure and problematic situations when dangerous experiments are available. This situation was already present in the traditional weblabs, because some infrastructures and experiments may also be damaged by student's interaction. To overcome this situation, the usual solution is to restrict student's access to specific actions over experiments, by limiting the functions available in the web interface.

In reconfigurable weblab, besides interacting with a specific experiment, students/teachers can also interact with the weblab infrastructure by changing I&M. This freedom poses some security problems solvable through two alternatives: i) restrict the reconfiguration options of the laboratory to teacher and technicians; or ii) provide a web interface for each specific weblab infrastructure, limiting the reconfigurable options open to students. This last solution will decrease the weblab flexibility since it requires a specific interface for each infrastructure or experiment. Regardless of the adopted method, all I&M should also be well tested and checked for compliance with the IEEE 1451.0, so not to damage the infrastructure. A solution is to have a unique trustful website integrating those modules such as the www.opencores.org website, or, in alternative, providing a tool able to check if those I&M are in fact compliant with the standard.

VI. CONCLUSION

Failing to observe a standard has hindered a larger collaboration between the academic fellows and institutions that have been developing and promoting the use of weblabs. Although there are some large consortiums (e.g. iLab, and VISIR, among others) that follow and share a common architecture in their weblabs, the adoption of a widely accepted and open accessible standard, like the IEEE 1451.0 std., would definitely contribute to a larger consensus around this educational technology, much in the same line of reasoning that led to the adoption e-learning specifications like SCORM. If one regards weblabs as a contributing educational tool (or resource) to e-learning in S&E courses, then quite reasonably the idea of adopting a collection of standards, such as the IEEE 1451 family of standards, for the development of sharable remote experiments, with permutable I&M developed and made available by different institutions, will increasingly gain acceptance in the broad community devoted to Engineering Education. Besides the presented technological grounds, it is also important to evidence that the development of weblabs, namely their underlying infrastructure and I&M, is, in itself, a didactical engineering activity for many graduating students. If, in a general development effort, one certain student develops a specific I&M that can be easily downloaded and used by the entire weblabs' community then a real engineering development case will have been demonstrated to that particular student. Giving the large number of experiments done in the training phase of engineers (not mentioning their particular area, e.g. mechanics or chemistry, among others), then one can quickly foresee the huge potential for collaboration in the development and utilization of remote laboratories and experiments, if (and this should be clearly stressed) a universal standard is adopted. In our view, the IEEE 1451 std. is clearly an option in this direction, following the rational presented in this paper.

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The Montegancedo Astronomical Observatory

The first free remote observatory for learning astronomy

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Abstract—**This paper describes the first open robotic observatory available to the public on the Internet (http://om.fi.upm.es), interactive and completely free access through a Web 2.0 application, which lets users manage professional astronomical devices and collaborate with other amateur users through a web browser. Its main goal is to open the astronomy to the society and that people learn informally about the cosmos by means of experimenting with real remote devices.**

Its architecture is made up by common collaborative Web 2.0 tools (such picture gallery, wiki, forum, chat, voting and discussing systems, etc.) and services and policies to offer meritocratically the observatory and its observing time.

The paper presents an innovative approach which proposes a reputation system for sharing an online resource to encourage high-quality contributions, and the initial outcomes obtained since the observatory started in December 2008.

This paper also describes the first experience using the observatory for carrying out online practical assignments in an Educational Innovation Project within the Technical University of Madrid during academic year 2008-2009 and using it for three subjects of these different degrees: Computer Science, Industrial Engineering, and Topography.

Keywords - informal collaborative e-learning; meritocracy; social networks; web 2.0; web laboratories

I. Introduction

In 2004 the term Web 2.0 was coined by Tim O'Reilly [1], describing the trend in the use of WWW technology and web design that aims to enhance creativity, information sharing, and, most notably, collaboration among users. These concepts have led to the development and evolution of web-based communities and hosted services, such as social-networking sites, wikis, blogs and folksonomies [2]. Wikipedia, YouTube, Facebook, eBay, Flickr or MySpace are only some famous sites as a result of the Web 2.0 [3][4].

Society have new habits, people spend more time on the Internet and access more frequently than a short time before. It is obvious it is happening a revolution around the Internet, in all the fields [5]. E-democracy, e-goverment, e-science, e-learning or e-portfolio are a few new concepts appeared in few years. The Internet has grown to currently become one of the most important ways for voluntary collaboratorion. It was the way used to develop successful systems like the GNU/Linux operating system, Apache server and other meaningful contributions through the Free Software movement. Everyday, thousands of people participate in some site on the Internet, from a simple suggestion in a recommendation system like Amazon, to the classification of a galaxy in an astronomical website like GalaxyZoo [6]. Other people donate their computing power to scientific research projects, through platforms like BOINC [7]. These and other collaboration ways are only possible thanks to the Internet nowadays.

However, the Internet lacks online websites for real experimentation, like the web laboratories where people practise and control resources through a web browser. This issue and the idea of taking advantage of the knowledge of thousands of volunteers collaborating day by day, were the motivations for carrying out the project presented in this paper. The aim of the research was to design a new methodology for creating collaborative projects and citizen participation, focused on education and based on real experimentation. This was supposed a new approach to create open web applications for society to promote the informal learning, the social constructivism and the generation of knowledge through collaborative, self-organized and meritocratic systems.

For this reason, to prove these ideas, it was necessary to develop a concrete example to apply the methodology. Authors opted for the Astronomy because it is a science with a huge number of amateur people. This is the origin of the Montegancedo robotic astronomical observatory.

The Montegancedo observatory is an informal e-learning Web 2.0 platform whose aim is to open Astronomy to the society in order to people learn and collaborate creating and supervising astronomical knowledge through the Internet. This remote observatory pretends to be a way of real experimentation in Astronomy, collaborative learning and, in general, dissemination of Astronomy.

Nowadays, there are hundreds of robotic telescopes, with different sizes and purposes, working autonomously without an operator. Some of these telescopes offer services through the Internet, both an interactive and non interactive way. However, up to now, in the most of cases it is required to pay for using these systems or are available only for few organizations, like schools or associations. Also it is appreciated that there is low interest in using these scenarios for informal e-learning and citizen research. So, in opposite direction, Montegancedo observatory meant being the first open observatory to the

This project would not have been possible without the funding support from the following institutions: the Ministry of Science and Innovation (AYA2009-14000-C03-03); the Technical University of Madrid (IE08100184 and IE09100154); and the Community of Madrid (S-0505/ESP/000237).

public through the Internet, interactive and completely free access (http://om.fi.upm.es).

This paper describes the Montegancedo observatory and the experience gained through its teaching approach. The document is organized as follows: Section II describes globally the system. Section III presents some of the most relevant collaborative services. Sections IV shows the experience in higher education context. Section V describes results in the first months of working. And finally, sections VI and VII present the conclusions drawn and the direction and priorities of the future work of the project, respectively.

Figure 1. Location of the Montegancedo astronomical observatory. Campus of the Computer Science Faculty (Technical University of Madrid)

Figure 2. Montegancedo astronomical observatory

II. Description Of The System

Montegancedo observatory is located in Madrid, Spain, at the roof of one building of the Faculty of Computer Science, as shown Figs. 1 and 2. From December 2008 up to now, the first remote experiment through the Montegancedo observatory is running. This experiment lets users watch the Sun and control a high-quality professional camera for astrophotography, as will be detailed later.

Any Internet user has free access to this observatory from a browser. It is worth mentioning that, dated November 2009 (only eleven months running), its community is composed by a total of more than 600 users.

The observatory is controlled through a web application. As said above, an advantage is that anybody can access to an professional astronomical observatory from anywhere. Consequently, people learn to control the devices, from simple webcams to powerful astrophotography cameras and telescopes. The control software developed for remote observatories, called Ciclope Astro, is scalable and adaptable to a large number of devices. Also it includes the potential of Web 2.0 services [8], which promote and make the collaboration and communication between users easier.

Next the most characteristic aspects of the system are described. Mainly it is based on a social network of virtual anonymous users and includes a great number of collaborative services, such as wikis, photo galleries, news publishing systems, suggestions, discussion and voting systems, and folksonomy or collaborative tagging, among others.

Social meritocracy is another important feature of this system by means of a reputation/karma users system. Besides promoting user participation, this is an innovative approach which lets schedule observing time in an original way described later.

A. Architecture

The infrastructure is composed by a server software, end-user applications, content syndication formats, instant messaging and astronomical devices control protocols.

It requires a client/server architecture, summarized in the Fig. 3. It is worth mentioning that the system combine leading technologies, such as Google Web Toolkit framework to develop AJAX applications in the Java programming language, and the iBatis persistence framework with a MySQL database.

B. Astronomical experiments

The main component of the Montegancedo observatory, and which is really appealing to users, is the set of astronomical experiments that users can do online. An experiment is referred to a set of objects, actions, devices and guides for its execution. An experiment could consist on observing the Moon, moving the telescope around the Moon's surface, taking photographs and building a mosaic with the photographs taken. Another experiment could consist on observing the Sun and calculating the Wolf number, that is, counting sunspots.

There are specific interfaces depending on the experiments and also the user roles. Up to now, different interfaces have been designed, from a basic hand controller to an advanced replica of Autostar II hand controller, going through astronomical object catalogs. A control interface of the Montegancedo observatory is shown in Fig. 4.

From December 2008, the first solar experiment is running. The goal of this experiment is to observe the Sun in H-alpha and distinguish sunspots and solar protuberances, apart from learning to control an astrophotography camera and change its parameters in order to take excellent photos. The telescope and the dome track the Sun, so users only watch an interface with four four real-time cameras broadcasting the video. Two of those cameras are used to watch the status of the telescope and dome. The other two are connected to the finder and telescope to observe the celestial objects. The parameters of these cameras can be modified from the interface, e.g., exposure time, gain, brightness, gamma and region of interest, and let user learn basic knowledge about Astronomy.

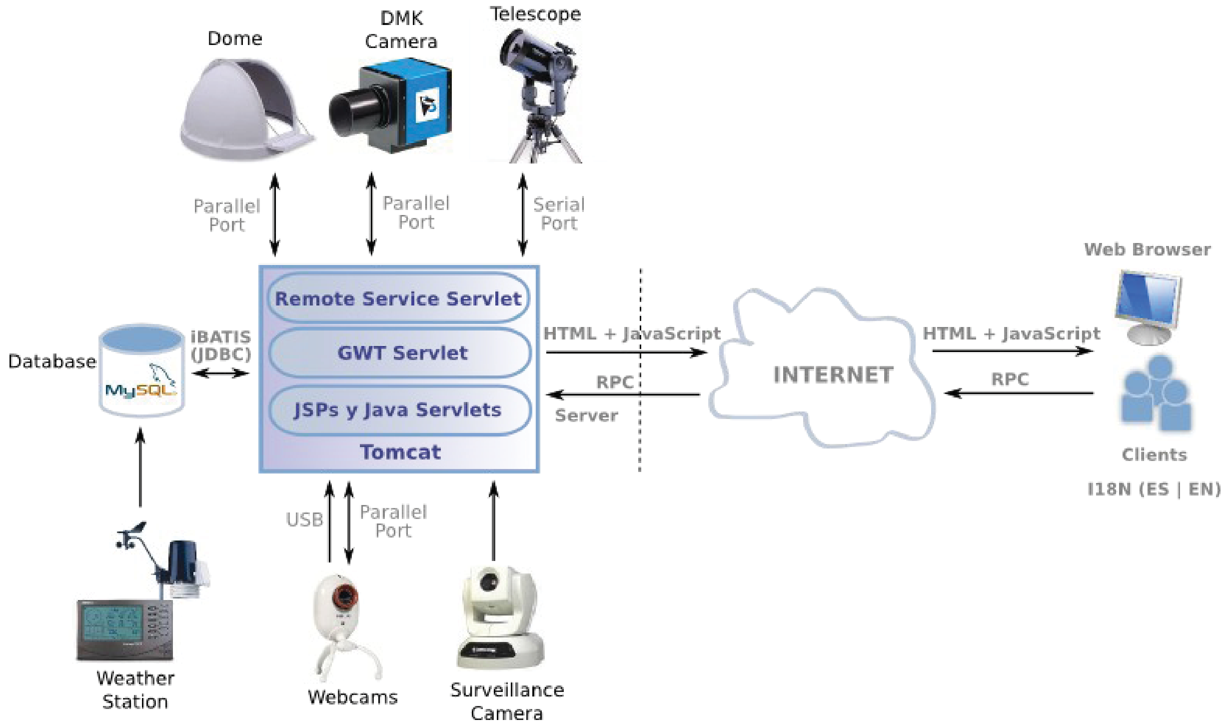

Figure 3. Montegancedo observatory's architecture

Another particular aspect is that to carry out each experiment there is a scheduling published on the website. In the case of the first experiment, each user has two intervals of ten minutes a day to control exclusively the observatory, as explained below. However, although an user has not the reservation or even is not registered, can observe what is happening during a session, since real-time cameras are broadcasting continuously through the web application. The drawback in this case is that the retransmission frequency is less than for the owner of the observing session, e.g., from twenty to one seconds.

C. *Observing Time Allocation*

In this subsection it is explained how observing time in this remote observatory is allocated innovatively.

First of all, user who wants to manage exclusively the observatory (telescope, dome and cameras) previously has to make a reservation in that interval. The web application publishes the reservations by means of a calendar, listing all the busy reservations made in a concrete day. A registered user has an interface in order to reserve the free intervals which are not reserved by other users. As said above, now in the solar experiment, the reservation policy only lets users reserve in the current day, from 00:00 AM. Website administrators are responsible of setting the timetable to carry out each experiment, the duration of each session, and the number of sessions a day per user. By default, the allocation policy is called FIFO (First Input First Output), that is, an user can reserve any free interval as they log in. However, these policies can be modified by the administrator according to behavior and feedback shown by the community.

Furthermore, there is implemented other policy based on a reputation system based on users' karma, that is, observing time per user is proportional to its karma. So, more karma, more observing time. This is a original way in order to compete for the available observing time using typical reputation technicals for Web 2.0. Basically, it is a manner of promoting and awarding to those most and best participative and collaborative users, and penalizing to damaging users for the community.

III. Web 2.0 Collaborative Services

One of the most important features of this system is the set of typical collaborative services for Web 2.0 incorporated in order to users participate creating and sharing knowledge, like collaborative edition through wikis, discussion threads or tagging through folksonomies. The synchronous communication by means of instant messaging also is fundamental to users exchange opinions, hobbies and knowledge. The social meritocracy is other of the most evident features of the Web 2.0. This methodology lets determine the karma of each user and other items within a remote laboratory based on the participation and acceptation of the rest of community. The fact of setting a user hierarchy is essential to encourage the motivation for competing for the use of online resources. And, in this sense, offering voting mechanisms is useful to organize the content of the collaborative systems. Next some of these services are described.

A. *Photo Gallery*

The photo gallery stores every astronomical photographs which are uploaded by the authors, both photos taken with own material and photos taken with the Montegancedo observatory.

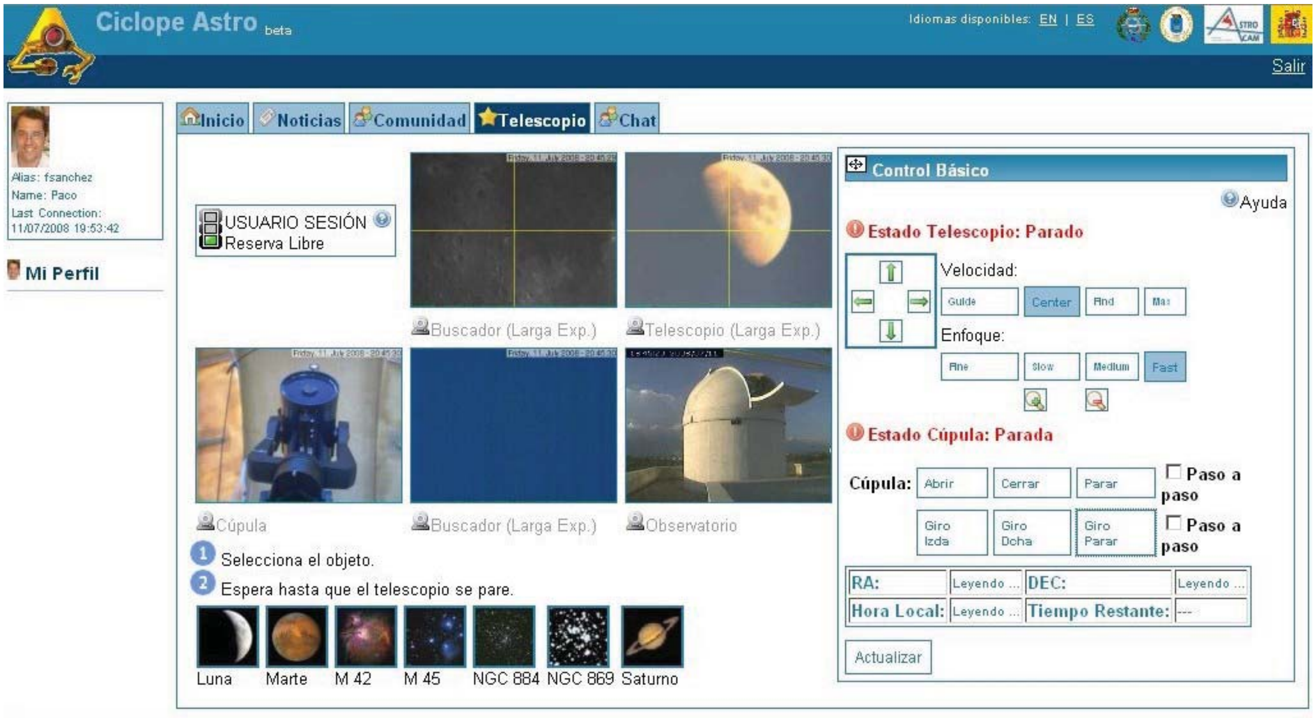

Figure 4. Control interface of the Montegancedo observatory: Observing the Moon

When an user uploads a photo, also has to fill a form indicating the title and the tags and, optionally, the rest of the fields regarding image processing, observing material, location, date and a free description about the photo. Each photo also has a karma associated and a global position which represents the importance and evaluation for the community.

B. *Meritocracy: Karma Reputation System*

Regarding to the meritocracy, karma is a parameter which measures the collaboration in Webs 2.0, a quantitative measurement of the user's effort within the community. The aim of the karma is to give more weight to the votes of those users who send the most and best contributions and best ability to determine the most valuable contents. As a result, content selection and hierarchy processes are accelerated.

All users obtain same karma value when they register in, but their karmas go up or down according a mathematical algorithm called PageRank, which is used by Google to order webs [9]. Essentially, users' karmas are calculated depending on quantity and quality of their contributions, votes sent and received, the attendance to live broadcasts (eclipse, occultation, etc.), that is, all set of own contributions.

Users are penalized if they carry out damaging actions for community, such as reserving observatory but not using, sending problematic photographs, etc.

C. *Suggestions*

Suggestions or proposals service lets users raise questions to the community. As far as community is concerned, they send suggestions and vote them. Users, anonymous or registered, vote proposals and, after deadline, close the process and award the winner proposal.

This service was used the first time to choose observatory name. In this case, name was chosen by means of democratic system where every vote has equal weight. The exhaustive survey process is described in Raquel Cedazo's doctoral thesis [10], besides the results obtained in comparison with a meritocratic system, where users have different voting weight.

D. *Wiki*

Its aim is that users edit collaboratively articles about Montegancedo observatory and Astronomy in general. Through this wiki, it is expected that users write astronomical articles which be useful to any Internet user, not only to observatory users. On the other hand, this wiki also is used for publishing terms and conditions regarding the use of observatory, press notes, related links, user guides for devices and functionalities, and results and statistics relating to experiments.

E. *Instant Messaging*

The observatory includes a synchronous communication as a virtual way communication among users. This instant messaging service is known as *chat*. It only can be used by registered users when logging in the application. It allows to open private conversation windows between two or up to five online users. Among main features, the chat allows to see any online user, set a own status message (busy, away, work, etc.), see online users' status messages and, finally, maintain a contact list. The chat divides connected users in two groups, those that are or are not on the contact list, so it is easier to locate favorite contacts.

IV. Experience In Higher Education

Montegancedo observatory was used in the 2008-2009 academic year for first time within the higher education context. Authors received a fund for an educational innovation project within the framework of the process of the establishment of the European Space of Higher Education and the improvement of the quality teaching. This project was entitled "Execution of collaborative remote practical assignments through Montegancedo robotic astronomical observatory. Applied to subjects: Geodetic Astronomy, Computer Vision, and Design for Web Applications ".

This project supposed to use Montegancedo observatory as a remote laboratory to carry out the practical assignments of three subjects of the three following Technical University of Madrid's centres: Computer Science, Industrial Engineering, and Topography. The target was to motivate students to put into practice the theoretical knowledge during lectures.

The three practical assignments were carried out by students after timetable through the Internet, and were focused on the solar experiment previously described.

Figure 5. Traditional methods to calculate the azimuth in practical assignments for Geodetic Astronomy subject (Topography)

The use of this system was specially benefit for Geodetic Astronomy subject, since practical assignments observing the Sun were canceled years ago because students were not safe running the risk of damaging their eyes by looking directly at the Sun, as shown Fig. 5. In this sense, Montegancedo observatory supposed to be a new opportunity to reincorporate it (118 students enrolled in 2008-2009 course), being out of danger and doing really comfortable for students, as shown Fig. 6.

This first year good experience [11] has caused that authors develop new experiments for 2009-2010 academic year. In this case, experiments are pretended to focus on calculating the azimuth, latitude, and longitude through observing stars at night.

V. Results

Data collected for analysis represents the collaboration of the users up to now. Statistical data are collected automatically into a database and analyzed subsequently. The experiment was successful in many aspects.

Dated 1st November 2009 and before one year running, there are satisfactory results: 609 registered users, almost 800 reservations, and a good participation and positive response: almost 150 photographs, 300 posts, 600 tags, more than 1000 votes, etc.

Furthermore, it is worth mentioning first results reflect that users access regularly, reserve the observatory, and take photographs. Even they use the other collaborative services, e.g., they upload and share their own astronomical photographs, edit wiki, send posts, votes, news, and suggestions, among others.

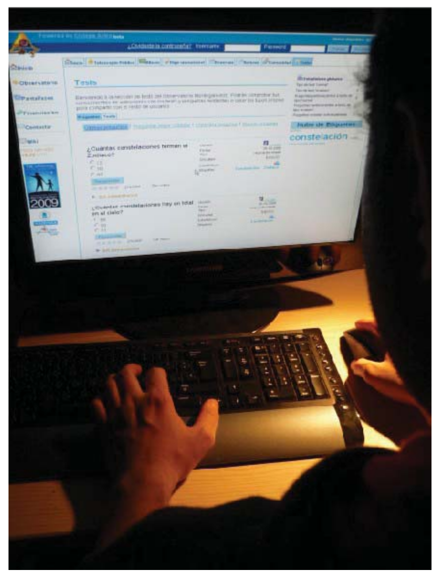

Figure 6. Montegancedo observatory' web controlled by a student from a computer

A. Social Network

Data analysis techniques are fundamental to understand how community works and its global behavior. The social network methods are particularly well suited for dealing with multiple levels of analysis and large communities [12] . Fig. 7 is an example of how visualization tools are useful to extract relevant information about the community [10]. So, it is possible to find out at first sight intrinsic aspects related to network structure or who are the most active users, the most influential ones, powerful, etc.

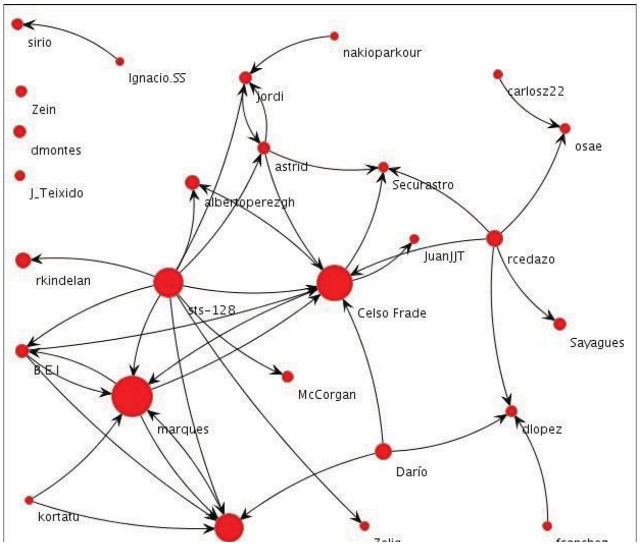

Figure 7. Graph which represents a observatory subnet and where it is possible to watch different sizes of the vertices to indicate the user karma. Links between vertices are votes

B. *Socio-demographic profile*

A users socio-demographic survey has been made in order to extract a pattern of the user profile. User data have been analyzed according to the age and gender, information required for the registration.

Regarding to active users, that is, those who have logged in at least once, gender statistics show that a high percentage of users are men (74.35%) in comparison to women (15.06%), as shown Fig. 8 and Tabla I. Meanwhile, the rest of the active users (10.59%) did not specify their gender since at the beginning these data were not compulsory.

With regard to age, Fig. 9 and Table II summarize that the predominant age corresponds from 20 to 44 years (73.64% over total).

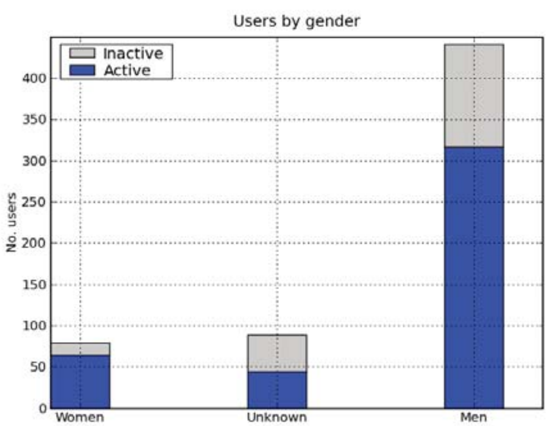

Figure 8. Statistics users: gender (5th November, 2009)

TABLE I. Users By Gender

Gender	Total	%Total	Active[a]	%Active
Female	79	12.97%	64	15.06%
Male	441	72.41%	316	74.35%
Unknown	89	14.62%	45	10.59%
Total	**609**		**425**	

a. Active users are who have logged in at least once

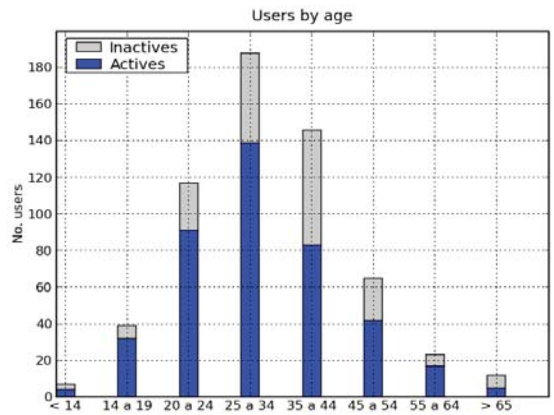

Figure 9. Statistics users: age (5th November, 2009)

TABLE II. Users By Age

Age	Total	%Total	Active[a]	%Active
< 14	7	1.15%	4	0.94%
14 to 19	39	6.41%	32	7.53%
20 to 24	117	19.21%	91	21.41%
25 to 34	188	30.87%	139	32.70%
35 to 44	146	23.97%	83	19.53%
45 to 54	65	10.67%	42	9.89%
55 to 64	23	3.78%	17	4.00%
> 65	12	1.97%	5	1.18%
Invalid[b]	12	1.97%	12	2.82%
Total	**609**		**425**	

a. Active users are who have logged in the system at least once
b. Invalid age refers to value less than 7

VI. Conclusions

As other authors have already proved, and as can also be observed from the Monteganceado project, the high potential of Web 2.0 tools allows to set up a large learning community, offering remote experimentation scenarios. Furthermore, one of the main features of this system is enhancing collaboration and participation through current well-known services on the Internet.

According to statistics collected, the experiment was successful in many aspects: high number of registered users; moderate number of reservations of the observatory; good quality content uploaded and written by users; and other collaborative tasks like writing, posting, voting, and tagging.

This paper has presented the experience using Montegancedo observatory to carry out practical assignments at the Technical University of Madrid. It has shown that this system offers huge opportunities for higher educational context.

Apart from being a project which could be used as a good example for designing new citizen science and e-learning projects in any other discipline, it will be a solution to face up to more and more data and to the insufficient number of experts needed for the review process of the astronomical tasks.

VII. Future work

One of the most ambitious objective is to build a network of free access remote observatories around the world, both hemispheres, to result in more observing time and more interesting experiments. Collaborations with amateur and professional astronomers will still be essential to design the remote experiments and to acquire the suitable material.

Gathering a large community that analyze data arrived from telescopes on this network is a socio-technical challenge and could be decisive to interpret astronomical phenomenons. Organizing this community and motiving them to collaborate in this initiative is a long-term objective.

Acknowledgment

This project would not have been possible without the funding support from the following institutions: the Ministry of Science and Innovation through "Collaborative Learning and Researching through an astronomical observatory controlled by the Internet" project (AYA2009-14000-C03-03); the Technical University of Madrid with two projects in Educational Innovation titled "Execution of remote collaborative practical assignments through Montegancedo Robotic Astronomical Observatory. Applied to the subjects: Geodetic Astronomy, Computer Vision, and Design for Web Applications" (IE08100184 and IE09100154); and the Community of Madrid through "ASTROCAM: Astrophysics Network of Madrid" project (S-0505/ESP/000237).

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Session 07E Area 5: Attracting and Retaining practices in Engineering Education

The Role of Superior Education Institutions on Post-Secondary (Non Superior) Education

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Action Research: A Way to Generate New Approaches to Teaching Mathematics in Bioengineering

Añino, María Magdalena; Perassi, Marisol; Waigandt, Diana Mónica

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Developing and Evaluating a Game-Based Project Management Learning Platform

Tseng, Ya Fen; Wang, Tsung Li

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Efectiveness of a Peer Mentoring Program in Engineering Education

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The Role of Superior Education Institutions on Post-Secondary (Non Superior) Education

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Abstract —**In Portugal, like in other European countries, people with strong professional competencies are encouraged to obtain higher education, no matter their age or their social condition. With their strong professional background and some theoretical aspects linked to scientific and technological domains, they become more helpful for the companies and for the society they belong. Considering these facts, the Portuguese Government developed specific legislation to attract new students for the technological higher education system. This legislation, intends to attract students older than 23, and also aims the improvement of technological education after the secondary school level. Pursuing this goal the Technological Specialization Courses (TSC) were created.**

The TSC are post-secondary, non superior training courses that will lead the students to obtain level 4 of professional training, according the 85/368/CEE decision of the European Union Council, published on the European Communities official journal. The TSC also allow people from different professional backgrounds to get technological training. The best students are allowed to access higher education in technological domains (basically in Engineering fields) and/or to the job market relied with the country's technological industries. Before the beginning of a TSC, the students are submitted to technological tests to determine their profile, which will be taken into account on the initial training, before the starting of the TSC.

In this paper, the success of TSC courses in Portuguese context is demonstrated, and the implementation of a successful partnership between University of Minho and the Technological Association for the Professional Education of Beira Interior (AFTEBI) is shown. The illustration of the successful partnership is done by presenting a case study of a TSC in Industrial Maintenance where the best students can pursue their studies in University of Minho, in the Mechanical Engineering Department in order to obtain a Mechanical Engineering Degree. The main role of UMinho (as Superior Education Institution) at different levels of this post-secondary (non superior) education is also discussed and highlighted.

Keywords: Engineering Education; Professional Training; Higher Education

I. INTRODUCTION

In the late seventies in Portugal the "Industrial Schools" have been extinct, under the assumption that equal opportunities meant a uniform non technical secondary level formative path for everybody. This transformation of the national education system under the Ministry of Education led to the rarefaction of the public offer of technical teaching, but also to the depreciation of the status of technical professions. To compensate the rarefaction or even lack of technicians with formal instruction to fulfill the available jobs, industry used to hire people that were initiated in the profession as apprentices, most of the time in situations that configure nowadays illegal infantile work [1].

From the information recently collected relative to professionals' availability resulted that maintenance and machinery operator positions presented a deficit of personal, both in quantity and quality [2]. It became evident that there were not enough Programmers/Operators of CNC Machines, Metalworkers, Turners, Welders, Mechanicals, Metrology and Quality Control Technicians, Product Development Technicians and other typical technical professions to fulfill market demand [3]. The main lacks in adequate professionals to fulfill industry needs occur in specific technical positions in those sectors, mostly technicians for undergraduate positions.

Also very few people respected eligibility criteria and the rules governing the quality certifications, safety and professional approval requirements of candidates' curricula, which turned the human resources scarce. The recent world wide economic slow down increased the difficulties for the less qualified, for they are less versatile to change profession, to perform new tasks or even to create new jobs.

By the beginning of the nineties the natural generation replacement led the shortage of skilled technical and technological intermediate level professionals in the industrial and business areas to a level that could no longer be ignored. Also the Portuguese Government inscribed competitiveness as one of the fundamental objectives for the Country in its Program, along with fomenting the social cohesion.

To achieve these objectives it is imperative that qualified people be available, for that is in fact the decisive factor for a sustainable long term progress, in particular in fast changing societies that are supported by knowledge and information.

Furthermore the installation of new technically demanding industries, and the competition for skilled people in Europe shortened even more the availability of skilled professionals in Portugal. The industry modernization in course and the challenges imposed by the fast changing reality demand that the new professionals be prepared not only to fulfill the present needs of the companies, but also to be prepared to permanently adaptation themselves to respond to emerging professions in areas that nowadays present already inadequate profiles.

In Portugal, because of remaining low education and professional qualification levels that still continue to characterize the great majority of the population in active age, in spite of the progresses already done in this domain in the last decades, this issue assumes special relevance.

It is then imperative to increase Portuguese skills and qualifications to create a potential for new opportunities and to promote both the people intrinsic development, and in consequence, the social, cultural and economical growth of the country. More qualified human resources generate larger competitiveness capability along with greater social cohesion. The educational system must be able to better qualify the youths, fighting in particular the high taxes of early school abandon (nowadays only half of the citizens aged between 20 and 24 has successfully finished the secondary education level). Also, to solve the inadequacy of the present skills of the work force to the emerging industrial opportunities, the formative offer must give new opportunities to adults, and promote school recovery and professional qualification, namely to those that are now facing unemployment because their jobs (even when skillful) vanished .

A careful analysis points to the development of solutions on technology learning under a solid technical teaching by trained professionals, to allow the graduates' integration in available work positions in present industrial companies, and to guarantee the adequate updating of the professionals already working, offering the possibility for the acquisition of new skills so making it easier their conversion and professional valorization.

In order to achieve the goals proposed in this work, the paper is structured as follows: section 1 is devoted to the presentation of the facing challenges; in section 2 the characteristics of the Portuguese Technological Specialization Courses (TSC), are presented; in section 3 is discussed the relationship between the University of Minho and the Technological Association for the Professional Education of Beira Interior (AFTEBI); followed by the presentation, in section 4, of the main characteristics of the successful TSC on Industrial Maintenance; in section 5 is discussed the success of this TSC and the impact on the caption of students for higher education; in section 6 is discussed the role of Superior Education Institutions on post-secondary (non-superior) education; finally, on section 7 are presented the conclusions achieved.

II. TECHNOLOGICAL SPECIALIZATION COURSES

The Portuguese Government assumed, in the "New opportunities" initiative, the minimum referential formation level goal to achieve 12 years for every youngster, having recently legislated the mandatory school frequency until finishing the secondary level or reaching 18 years old [4]. This goal was assumed in couple with the goal of increasing the rate of students attaining technological and professional courses at the secondary education level to at least half the younger population. The bet is not only that the new generations may reach higher education levels, but also that they get adequate professional qualification prior to enter the job market, namely by providing professional education oriented to professional profiles and skills that are in deficit and highly required.

Knowledge through professional teaching and formation must be conciliated with a qualified professional insertion component. Seeking the access to higher education and equal opportunities, and envisaging the engagement of more young and adults with the professional education and formation system, the Government assumed, in its program commitments, to enlarge the formation offer along the life to new publics. It was also decided to involve the higher education institutions in the expansion of the post-secondary formation, in order to grant the articulation between the secondary and superior teaching levels and the system's accreditation, for superior studies pursuit purposes, of the post-secondary formative courses specialization.

To materialize these commitments, the present law promotes a deep reorganization of the technological specialization courses at the levels of the entering access, the formation structure and the conditions to access higher education institutions for the graduates of this system.

Being aware of the Portuguese lack of skilled professionals, the Ministry supported the creation of a set of Technological Schools intending the promotion of initial formation in technological areas for youth, in a post secondary level. These courses later acquired the designation of Technological Specialization Courses (TSC), granting Level IV of professional qualification through Technological Specialization Diplomas (TSD). The TSC are especially encouraged in sectors or areas in which the companies are strongly lacking competent technicians, giving the youths a larger warranty of immediate employability, after the conclusion of the apprenticeship.

The technological specialization courses are post secondary non superior level grades, that seek the acquisition of the IV level of professional formation, as defined by the n. 85/368/CEE Decision, of the European Council, of July 16, that was published in the n. L 199 EC Official Newspaper, of July 31st, 1985.

Level IV of professional formation is obtained through the conjugation of a general or professional secondary level formation, with a post secondary technical formation and it is characterized by:

- Being a high level technical formation;
- The resulting qualification includes knowledge and abilities belonging to the superior level;
- Mastering the scientific foundations of the different studied areas is not demand, in general;
- The acquired knowledge and abilities in this level allow the assumption of autonomous responsibilities in conception, direction or management.

These courses aim to join the formation and learning components to the job market demand. The materialization of these objectives is done not only by the promotion of partnerships between formation schools, higher education institutions, but also by involving business responsibles and employers, seeking to direct learning activities to effective professional insertion, and to assure actual recognition of the subjects learned for higher education studies pursuit purposes.

In the analysis of the Idea Proposals for the creation of new Technological Schools under PEDIP II (II Programa Estratégico de Dinamização e Modernização da Indústria Portuguesa), the second Strategic Program for the Dynamization and Modernization of Portuguese Industry, a concern emerged to use already existent infrastructures in order to make the best use of the incentives that they had been attributed previously, namely under the preceding PEDIP program.

On the other hand, most schools are not supported in autonomous infrastructures, and so larger operation flexibility is possible, including the continuous access to new technologies, methods and formation methodologies, through the celebration of collaboration protocols between Institutions, so avoiding the duplication of investments in the same areas.

This Specialization Courses present advantages for the youth: with strong technological component are lectured by competent technicians. Now are offered under cross collaboration among Technological and Professional Associations, such as AFTEBI, with institutions of the Portuguese Superior Level System, such as the Universities of Beira Interior and Minho, and the Polytechnic Institutes of Guarda, Castelo Branco and Viseu [5].

III. PARTNERSHIP "UNIVERSITY OF MINHO / AFTEBI"

AFTEBI is an Association for Technological and Professional Formation, created in 1997 in the interior center of Portugal, with 12 years of experience in the formation of intermediate level professionals for the industry in various knowledge areas.

The University of Minho (UMinho), founded in 1973, is located in the Minho region of Northern Portugal, a region with a strong tradition of entrepreneurship, essentially of small and medium-sized businesses. The University of Minho was strategically planned with the surrounding socio-economic environment in mind, aiming to contribute to its development.

By 2001 AFTEBI made an invitation in to the University of Minho to enlarge the activity of AFTEBI to the North of the Country. This partnership is now translated in several cooperation forms, formalized through protocols to encompass the following objectives:

- To take advantage of the University human resources (namely in pedagogic coordination of the courses and lecturing) and infrastructures (pedagogic facilities and equipments);
- For Prosecution of studies of the AFTEBI graduates in the 1st cycle superior courses promoted by the University of Minho.

Due to the large spectrum of formative areas in which AFTEBI is acting, not all of the Technological Specialization Courses are running in the North of the Country, but all of them are validated by the UMinho not only for studies prosecution, but more importantly, for scientific approval of the knowledge domains lectured.

Actually the intervention of UMinho has grown significantly in recent years, not only by the enlargement of the formation areas, but also by the number of students that attend the formation courses, as it may be observed in Fig. 1. and Fig. 2. Additionally, the employability rate of AFTEBI students, graduated in partnership with University of Minho (Fig. 3.) is high.

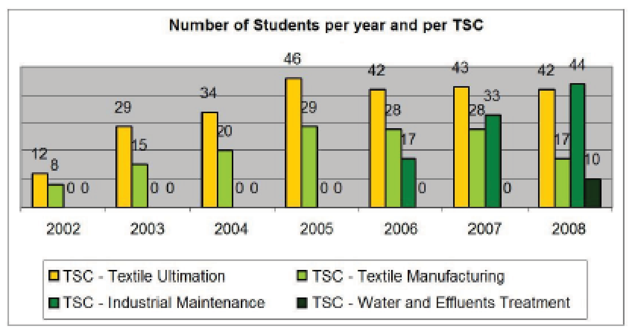

Figure 1. Number of Students per year and per TSC

A. Protocols

With the first graduates in 2003, a protocol of studies pursuit was signed, establishing the rules and molds for the graduates access the superior level courses promoted by the University of Minho. This protocol has been updated whenever any of the institutions introduced changes in their courses, the most recent update having happened in January 2008.

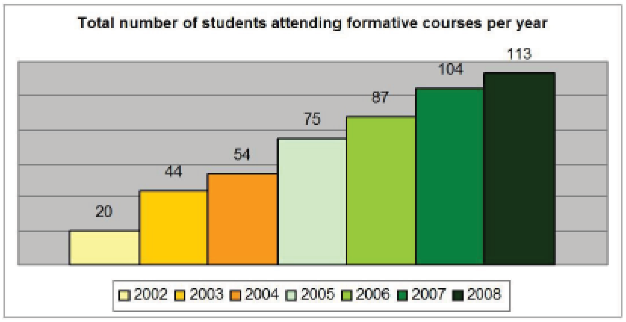

Figure 2. Total number of students attending formative courses per year.

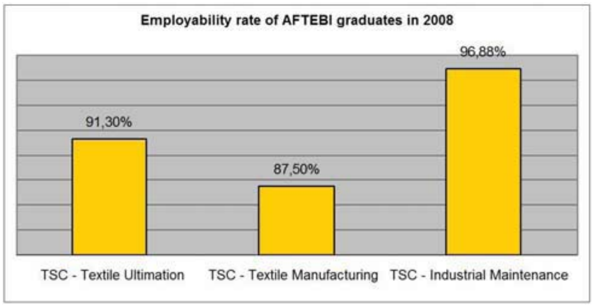

Figure 3. Employability rate of AFTEBI graduates in 2008

B. *Technological Specialization Courses*

In the year of 2009, the following Technological Specialization Courses were active:

- Textile Ultimation;
- Industrial Maintenance;
- Water and Effluents Treatment.

It is foreseen that the formation areas be kept in the outburst of the scholar year 2009/2010, with a probable replacement of the textile area by two possible courses to be promoted:

- Industrialization of Fashion Product;
- Fashion Commerce.

The decision will always be made in agreement with the expectations of the industrial area employers, because, besides the increasing youths' qualification and their pursuit of studies, one of the main objectives of this formation is the placement of intermediate professionals in the industry.

IV. Technological Specialization on Industrial Maintenance

A Specialist Technician in Industrial Maintenance is a professional that, autonomously or integrated in a team, makes the diagnose, prepares, plans out or accomplishes several tasks of corrective, preventive or "on condition" maintenance with the objective of guaranteeing the maximum readiness of the equipments and industrial facilities, for them to produce with quality and guaranteeing the execution of the production programs.

AFTEBI Technological Specialization Course professionals are graduated with a high level of technical specialization in the domain of the Industrial Maintenance (Fig. 4.) with a strong practical component in the areas of specialty of the mechanics, electricity, electronics and automation.

Formation Plan					
Scientific and General Formation Component					
Formation Institution	Association for Technological and Professional Formation of Beira Interior				
Technological Specialization Course	Industrial Maintenance				
Competence Area	Formation Curricular Unit	Work hours		ECTS	Comments
		Totals	Direct contact		
(1)	(2)	(3)	(4)	(5)	(6)
Languages and communication	Technical English	53	32	2	
Citizenship and society	Labor Relations and Law at work	27	16	1	
Organization and Management	Hygiene and Safety at work	40	24	1,5	
Organization and Management	Introduction to enterprise management	27	16	1	
Organization and Management	Cost Analysis	40	24	1,5	
Citizenship and society	Quality and Environment management	53	32	2	
TOTAL		240	144	9	

Figure 4. Formative plan for Industrial Maintenance TSC.

The reinforcement of the technical capacity in these areas constitutes one of the fundamental objectives for the modernization of the industrial companies, and these graduates will be prepared to:

- analyze technical documentation of diverse nature (sketches, drawings, facilities' diagrams, manuals, manufacture catalogs, standards and procedures) relative to the equipments, systems or facilities of mechanical, electrical or electronic nature;
- execute outlines and drawings of facilities and connections electromechanical, electrical or electronic circuitry, as a support to the maintenance activity;
- prepare the tools, materials, components, and parts that are necessary for the development of the maintenance routines;
- execute the installation of equipments or systems of electromechanical, electrical or electronic nature;
- accomplish the operational, functional or officinal rehearsals in electromechanical, electrical or electronic equipments, systems or facilities, so assuring their conformity with the specifications of the project and quality standards;
- follow the performance of the equipments, systems or facilities of electro mechanical, electrical or electronic nature, in agreement with the established in the maintenance plan;
- propose modifications in equipments, systems or facilities of electro mechanical, electrical or electronic nature, taking in account the deviations between the rehearsal values and the pre-established parameters;

- execute interventions and to repair the equipments, systems or facilities of electromechanical, electrical or electronic nature in order to improve their operational characteristics;
- propose alterations to the layout of the systems, productive or operating equipment, with the objective of improving their performance;
- elaborate technical reports about the accomplished interventions;
- do maintenance plans, based in the historical reports of the equipments, systems or facilities of electromechanical, electrical or electronic nature;
- cooperate with the productive area, with the objective of optimize the resources and to reduce unproductive times;
- detect mistakes and technical deviations that may happen, to analyze them and to propose solutions;
- develop technical relationships with the suppliers of equipments, to analyze the adaptation needs of the technologies to the specificities of the company;
- analyze the equipment needs and provide their acquisition;
- promote and apply preventive maintenance practices.

By the conclusion of the TSC plan of formation, it is expected that the students possess a set of competences, not only at the level of the theoretical knowledge acquisition but also at the level of its practical implementation.

The TSC of Industrial Maintenance has the duration of 1560 hours 600 hours of which in industrial context. The formation has a strong practical component, 75% of the total hours of the course being supplied in laboratorial/officinal context. For this formation the facilities of the UMinho, of the Technological CITEVE (Centro Tecnológico para a indústria Têxtil e do Vestuário) – a Portuguese technological center for textile and clothing industry, and Industrial companies are used.

Students are stimulated to develop knowledge interests at the levels of know-how to do and know-how to be, seeking creativity and innovation. Also they are taught about industrial needs for workers with their profile in order to assure their own dynamic development, that collaborate by guaranteeing the apprenticeship of all the students that benefit in consequence of good job perspectives.

The Pedagogic Coordination of TSC of Industrial Maintenance, from the Department of Mechanical Engineering of the UMinho, is supported on a group of specialists and technicians of each area that come not only from educational system, but also from industrial origin. Program contents and methodologies are periodically checked and adjusted if needed with the objective of meeting the real needs of the industry. In Fig. 5 the part of the formation plan that corresponds to the Technological Formation is presented. In this map some notations are used, more precisely:

- in column (3) the total hours of work are indicated as defined in Portuguese Decree-Law n. 42/2005, from February the 22nd;
- In column (4) is indicated – among the total hours of work – the direct contact hours (with teacher), according the definition presented at point d) of the article 2nd of the Portuguese Decree-Law n. 88/2006, from May the 23rd;
- In column (5) is indicated – among the total hours of direct contact – how many hours are dedicated to practical applications, namely laboratory, workshops and/or Project according the point 2) of the article 15th of the Portuguese Decree-Law n. 88/2006, from May the 23rd;
- In column (6) is indicated the number of ECTS, complying with the European Credits Transfer System, according the Portuguese Decree-Law n. 42/2005, from February the 23rd.

Technological Formation Component						
Competence Area	Formation Curricular Unit	Work hours			ECTS	Comments
		Totals	Direct contact			
			Totals	Practical		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Basic Sciences and Technologies	Mechanical Technology	80	48	36	3,0	
Basic Sciences and Technologies	Maintenance Welding	80	48	36	3,0	
Basic Sciences and Technologies	Electrical Installations	93	56	42	3,5	
Basic Sciences and Technologies	Electrical Equipments	93	56	42	3,5	
Basic Sciences and Technologies	Electronics	107	64	48	4,0	
Basic Sciences and Technologies	Automation and Industrial Robotics	133	80	60	5,0	
Basic Sciences and Technologies	Diagnostic and Repair Techniques	133	80	60	5,0	
Basic Sciences and Technologies	Technical Drawing	107	64	48	4,0	
Basic Sciences and Technologies	HAVAC Systems	80	48	36	3,0	
Basic Sciences and Technologies	Electromechanical Maintenance	80	48	36	3,0	
Basic Sciences and Technologies	Maintenance Org. and Management	107	64	48	4,0	
Basic Sciences and Technologies	Management of Supply and Stocks	53	32	24	2,0	
Basic Sciences and Technologies	Energy Audits	53	32	24	2,0	
Basic Sciences and Technologies	Project	160	96	72	6,0	
TOTAL		1360	816	612	51,0	

Figure 5. Technological component plan for Industrial Maintenance TSC.

The main factor of success of this TSC is connected, fundamentally, with the vicinity of the industrial business and the correct detection of their need for intermediate technicians, and to the establishment of partnership protocols with Entities, Schools and Companies, that guarantee the high patterns of quality of the supplied formation.

The success of this TSC may be measured by these technicians' high demand in the industry being translated, consequently, in high employability rates.

V. DISCUSSION – TSC ON INDUSTRIAL MAINTENANCE

The industrial network of the north of Portugal is characterized by industrial companies of small or medium-size dedicated to the textile, mechanics, shoemaking and wood industry. These companies have been very active and versatile being competitive so far.

Nowadays, these industrial companies are object of profound changes due to the national and international situation, particularly related to globalization of the economy.

These companies are undergoing great transformations - from a situation where they based their competitiveness on non-skilled low cost labor – to a new reality where they must adopt a strategy to develop and produce innovative products with high level of added-value. In this context the technological formation of workers, more or less qualified, is the key for the success and especially the technological formation of well trained technicians for operating and maintaining the industrial equipments is crucial. These equipments are technologically sophisticated and allow the companies produce high added-value products. In this scenario, any technological formation course in Industrial Maintenance is, only by its existence, a guaranteed success.

The existence on a region like Minho (in the northwest of Portugal) of higher institutions (UMinho) and Professional Schools (ETT) and the cooperation work of those institutions for common objectives (improvement of the performance of the region's industry) based on their resources sharing (physical and human resources) is a strategic and useful service for the industrial companies, for the region's people and respective quality of life, and for the country.

The TSC on Industrial Maintenance of the ETT is coordinated, from the pedagogical point of view, by University of Minho. This fact brings the guarantee of the quality and success of the contents/programs of the curricular units that compose the formation plan. Also, some technological Curricular Units are assured by teachers from University of Minho. UMinho shares with ETT some teachers, highly qualified, for organizing and teaching some technological curricular units, related with key areas of Industrial maintenance field. This is, clearly, an added value for the TSC on Industrial Maintenance. Also, the knowledge of the industrial reality, by UMinho's teachers, is very important to adapt the pedagogical contents of the curricular units, directed to the real needs of the industrial companies. This solid knowledge of the industrial reality is the result of many years of cooperation between UMinho and industrial companies of the region.

Due to the teaching load, the TSC on Industrial Maintenance is specially focused on aspects linked with the practical application of the theoretical aspects of the studied maters. As these professionals are going to be – some of them – responsible for maintenance teams on their industrial companies, the theoretical aspects (even if 75% of the total hours of the course are supplied in laboratorial/officinal/industrial context) are carefully highlighted on their formation.

The aspects relied to Competence-Based Education [6] are highly considered during their formation. The concept of competence-based education may facilitate learning [7] in a society of rapid change and complexity. The solid theoretical formation and the posterior application on practice [8] gives, to these students after the conclusion of the TSC, strong skills on domains related with Industrial Maintenance.

Complementarily, on their formation, several areas like mechanics, electronics, informatics, automation and industrial robotics (Fig. 5) give, to these students, skills that are highly valuated and searched by the industrial companies. Commonly very good maintenance technicians may be found in the region, but their basic formation is on only one of the above mentioned areas. The fact that this TSC the formation has a solid and complete coverage, considering all the areas of the field of industrial maintenance, gives the trainees a basic formation with a high level added- value. Nowadays, more than in the past, the industrial equipments incorporate complex devices that interact between them, and any operator/maintenance technician that needs to interact/repair with these devices must have a complete and solid background at several and complementary fields related with Industrial Maintenance.

In the practical/training classes, as in the project developed in industrial companies, advanced teaching techniques are used [9], namely advanced formalisms and informatics tools in order to give the student a faster and more detailed description of the reality that they will find at work in real world. These tools are very important for level 4 technicians that are expected to assume, in a near future, responsibilities of leadership on their companies.

As a result of this reality, presented above, the students of the TSC on Industrial Maintenance are well accepted and searched by industrial companies and they reveal to have the necessary and adequate skills adapted to their needs.

But the real capabilities and skills of the technicians, that finish the TSC on Industrial Maintenance, are not only interesting for industrial companies. UMinho, too, is a possible choice for them, in order to continue their formation in the domain of Mechanical Engineering.

As a strategic University, UMinho intends to have the best students in all the domains. In the particular case of Mechanical Engineering - the possibility of having students with a practical background acquired and based on competence-based education concepts - highly focused on the Bologna declaration [10] becomes interesting to attract this students, namely the best ones of the TSC on Industrial Maintenance, for their graduation on Mechanical Engineering domain.

As a formalization of this idea the agreement signed between UMinho and AFTEBI considers this possibility and allows the access - to the Integrated Master on Mechanical Engineering of University of Minho - of the five best students of the TSC on Industrial Maintenance. This agreement respects and is in accord with the Portuguese Decree-Law n. 88/2006 of May the 23rd. This Decree-Law defines the rules for the TSCs and provides the possibility, for the students that finish their TSCs, of continuing studying on Higher Education Institutions.

The selection of the students, for accessing the Integrated Master on Mechanical Engineering of University of Minho, is done taking into account the average classification that they have obtained in the end of their TSC on Industrial Maintenance. Recognizing the previous quality formation of the students, it is, also, previewed the possibility of some equivalences of Curricular Units, when the students are admitted to the University. The actual decision any possible Curricular Unit equivalence belongs to the Director of the Integrated Master on Mechanical Engineering and it is regulated by the point 27th of the Portuguese Decree-Law n. 88/2006 of May the 23rd. This decision is taken, from an objective point of view, mainly based on the analysis of the students' curriculum. This possibility of equivalences is one important point to motivate the best students to pursuit their studies in the University.

In the scholar year 2008/2009 the five places available (for the Integrated Master on Mechanical Engineering of University of Minho) were completely taken and concurred, for these five places, twelve students. That shows the interest, of the students, for continuing their studies on the University and the utility of this strategy to attract different publics for Higher Education Institutions.

Being this year the first year that the experience is carried out, the first semester evaluations show that these students have had satisfactory results. A more complete evaluation, about the performance of these students, will be done in the final of the first year; until now, it was not possible because the first year is running. Moreover, the first conclusion that can be confirmed is that these students – because they have a basic background on several domains, related with mechanics, electronics, informatics, automation and industrial robotics – have more facility to understand some aspects and concepts related with the domain of Mechanical Engineering, when explained to them by the first time, and when compared with the other students that have not this basic background. It must not be forgotten that this students, despite having a basic background on several technological fields, are performing students too (they were the best of the TSC on Industrial Maintenance) and they can be an added value for the respective industrial units, after their graduation.

VI. The Role of University in the Post–Secondary (non superior) Level Teaching

The model so far presented is still in its earlier implementation days. Concerning the particular case of the UMinho/AFTEBI partnership in Industrial Maintenance, only two courses have been completed, and a third is going to finish this year. Anyway a discussion may start about the role that the High Education institutions are expected or should play in the definition and support of the post-secondary training/educational activities. Also it may be important to widen the look to the entire educational system, with particular emphasis in the developing technological subset that nowadays is growing under the umbrella and support of ministries other than the Education Ministry, like the Ministry of Labor or the Social Affairs, alongside with the conventional educational system, ruled by the Education Ministry.

In despite of the equal opportunities rhetoric of the late seventies that lead to technical formation disaster in Portugal, the technical courses made their way simple because they are a basic need in a developed society.

The experience reported above is only one case in the Portuguese reality nowadays. Different social and technical environmental realities must certainly be encompassed by different solutions, and the risk of wrong decisions is also diminished by the diversified offer that can be designed this way.

The University may act in diversified grounds in respect to the learning/teaching activities. As a matter of fact it must be stressed that the University is responsible for the scientific preparation of the bulk of the teachers of the system, but the research activities committed to the Universities in Portugal are also responsible to foster development, in particular in technical issues. Any discussion about technology, at any level, should involve the main actors in the country, either from the side of the end users of the skills (the companies), from the producers of knowledge (Universities and Polytechnic Schools) and also from the providers of trainees and ultimate beneficiaries of the system (the society).

According to IQF, (Institute for Quality in Formation) this learning model must be structured in a group of phases, processes and support instruments from the conception of programs, courses and pedagogic solutions, that can be explored and used in different ways, that is, as a function of the needs and readiness for the entities and professionals that intervene in the formation.

The formation including apprenticeship in context of work, guaranteed by the Schools through a Pedagogic Coordination of the courses that contacts and selects the housing companies, usually interested in the technicians under formation given is a guarantee not only to employment, but also to adequate choice of qualifications to be acquired.

The diploma obtained in the technical courses engaging the possibility of accessing Higher Education Studies, granted by written agreements between the institutions involved, allows an alternative via to access higher level. This alternative may lead in future to a more equilibrated choice at the lower levels, by defusing the anguish of a precocious decision.

As a potential receiver of the trainees that may want to proceed studying and taking in account that some formation credits acquired in the Technological Courses may be considered for prosecution proposes, the University must be involved in the actual design of the courses.

However limited nowadays, the number of student positions offered by the University may increase as the Courses become more consolidated and recognized by the society.

The issues linked to the evaluation, seem to be fundamental for the understanding of the effective role of the formation while instrument of development, according with Lima Santos and Pina Neves [11] . It assumes special importance in the materialization and regulation of the formation actions from the evaluation being a systematic dynamic and intrinsic process, to the formative process, contributing to the promotion of their global success

The formation must be conceived from the start considering the needs, to design the formative proposal, to organize the pedagogic sequences, in order to bring together the technical and pedagogic resources and to prepare support equipments.

In this context, Parry [12] referred that a formation activity performed well happened when "the right trainees (taking in account the process of selection made) develop the knowledge, the competences and the necessary attitudes (contents of the formation), through means, strategies and appropriate teachers (process), in a certain time and in a certain space (context), fulfilling the initial expectations (…) (objectives and expected results for the acting).”

VII. CONCLUSIONS

Among the reasons motivating the efforts of launching and supporting technological specialization courses, the most important is undoubtedly the high number of skilled people that is needed every year and that must undergo a training process.

It is well known that experience improves performance. Although the amount of experience needed to achieve a certain level of performance varies with the individual and personal characteristics, some experience is always desirable.

Creation, improvement and/or adaptation of methodologies that improve adequacy to the needs felt by the companies will not only improve the employment rates among youngsters, but also may allow to minimize or overcame the inadequacy of skills occurring due to technical knowledge change.

In this context, the TSCs provide some solutions:

- From the student's point of view, a better formation by the end of the secondary level is provided, enlarging the capacity to access the Job market;
- From the companies' point of view, the availability of new graduates enlarges the access to a more qualified work force;
- From the formation schools point of view, as for instance AFTEBI, the accomplishment of its mission results in a better and wider professional formation of a larger set of people;
- From the higher education Institutions (like the UMinho), the contribution to the quality improvement of the technological specialization courses of (through their pedagogic coordination) and by the attraction of its best students for continuation for superior studies in a very important area for any developed country, engineering;
- From the national point of view, the creation of conditions to improve the technological capacity of the country and also a sustainable development of the Portuguese society (either at the level of the companies by the availability of more specialized technicians, or by the fact that some of them may access higher education, that, otherwise, would not be possible).

The University must be involved with the forming entities and the companies in the definition of the global objectives to reach and activities to develop, and also in the assessment of the Courses, in order to assure the technical quality of the formative proposal, its coherence and robustness.

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Action Research:

A Way to Generate New Approaches to Teaching Mathematics in Bioengineering

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***Abstract*— Bioengineering, a relatively recent engineering branch, was launched 24 years ago in Argentina at our university (Universidad Nacional de Entre Ríos). The undergraduate program aims at providing solutions to health problems through the application of advanced technology. Consequently, a highly skillful professional is required. However, learning deficiencies and difficulties have been observed among first year students. Action Research was chosen as a research tool to generate new approaches to teaching mathematics in Bioengineering.**

Keywords: Biomedical Engineering Education – Action Research – Teaching/Learning Mathematics for Bioengineering Introduction.

I. Introduction

This paper accounts for the origins, objectives, methods and first results of an Action Research project concerning the teaching of mathematics to future bioengineers. The project is being carried out within the bioengineering undergraduate curriculum at the Faculty of Engineering (Universidad Nacional de Entre Ríos). Biomedical Engineering or Bioengineering is a recently developed Engineering branch. In our country it was launched 24 years ago at our University in order to provide solutions to health problems through the application of advanced technology. Consequently, a highly skillful professional is required with solid mathematical background, for example in the field of technology applied to imaging diagnostic systems such as computerized axial tomography (CAT) which relies on the inverse Radon transform. Mathematics also interacts with Computing and Biology in the modeling and simulation of human organs, computer assisted surgery, tumor growth and the immune system modeling, prostheses design and other health related areas. On the other hand, technological changes in all areas related to the engineering field occur at a great speed. In Latin American countries, both established and modern techniques are in use, so universities must offer courses of study designed to develop creative engineers capable not only of understanding the new technologies but also of adapting them to the true needs of society. Bioengineers should also be prepared to develop innovative systems and techniques while interacting with specialists from other disciplines without losing sight of the economic, social and environmental impact of their developments. There is general consensus, thus, that Engineering undergraduate teaching courses, especially Bioengineering ones, should provide the students not only with solid background knowledge, but also facilitate the development of cognitive, metacognitive, affective and social learning strategies to foster learner autonomy and critical thinking which will serve to evaluate information and lead to continuous learning. From this analysis, it is clear that the Mathematics courses in the Bioengineering curriculum (See Table I) must be planned in such a way not only to foster the acquisition of the necessary mathematical concepts, procedures and methods to cope with the subjects in senior years, but also to contribute towards the development of abstraction, and of critical and reflective thinking.

TABLE I.

Year	First Semester	Second Semester
First	Calculus	Linear Algebra and Analytic Geometry
Second	Vector Calculus	Differential Equations Statistics
Third	Functions of a Complex Variable	

a. Mathematics Courses in the Bioengineering Curriculum

As a result, a strong emphasis should be placed on learning to learn Mathematics This means that the student should be involved in a process of discovery about learning the general mathematical abilities so as to be sufficiently equipped to face the study of new areas of this discipline according to his/her needs and interests in the future. In furtherance of this, it is necessary to adopt a learner-centered approach to stimulate the development of such abilities. Far from being a passive subject, the student will have an active role in the teaching-learning process. Although the members of this research team agree with this point of view, designing and implementing new teaching and assessment tools is far from being an easy task for the Mathematics teacher in charge of the course corresponding to the first years of the Bioengineering curriculum. Generally, the groups are numerous and students come from different parts of the Entre Ríos province and from other provinces of our country. Consequently, the mathematics background after high school is diverse. However, this may be taken on as a challenging situation by the teachers.

II. MOTIVATION

Two opposing issues triggered this research project: on the one hand the demanding professional requirements imposed on bioengineers and the goals of the mathematics courses in the curriculum mentioned above and, on the other, the complex issues concerning students who enter our university program.

The difficulties that bioengineering students face during the first years of the course of study have been a cause for constant worry at our college. An analysis of withdrawals shows that different factors interact to influence this complex phenomenon: homesickness, vocation conflicts, socioeconomic problems, insufficient schemata, poor or bad study habits, among others. In the mathematics class, there is evidence of problem-solving, reading comprehension and academic writing problems that are then reflected in low marks. During the past five years, more than 55% of the students were bound to retake the course. This situation raised a series of questions that encouraged this research project: In our role as teachers in the Bioengineering curriculum, do we foster critical reflection on our students' learning strategies? Can we design and use didactic strategies in our classroom to enhance reflective reading and writing and to generate motivation, draw students' attention to the comprehension of concepts and encourage their active, reflective and critical participation during the mathematics teaching-learning process?

These worries were the starting point for the formation of an interdisciplinary group whose members study the above stated problems in a group of second-year students who are taking the subject Vector Calculus and Differential Equations.

III. METODOLOGY

Action Research was chosen as a research tool to carry out our project. The term "Action – Research" was first coined by Kurt Lewin, a social psychologist, in about 1947 [1]. Lewin's research method was not aimed specifically at education but at social practices in general. During the '70s, researchers from Great Britain and Australia put forward an alternative education research paradigm based on Lewin's model. Both John Elliot and Lawrence Stenhouse in Great Britain and Stephen Kemmis in Australia sought new ways of producing knowledge not only about the teaching-learning process but also about curriculum development and implementation [2], [3], [4]. In Latin America, the lines of enquiry developed by Paulo Freire, Orlando Fals Borda and Joao Bosco Pinto emphasize popular and informal environmental education [5], [6]. Currently, Action Research as a movement has gained strength in many countries such as Great Britain, Australia, the United States, Canada, Spain, Germany, Austria, Brazil, Colombia, El Salvador and Argentina, among others.

These lines of enquiry focus on different aspects. According to Elliott, Action Research explores situations in which teachers are involved, a sort of teacher initiated form of classroom based research aimed at improving practice. Wilfred Carr and Stephen Kemmis believe that the aim of Action Research is far from finding general pedagogic formula. Thus, it does not make any claims for universal relevance. Instead, its essential impetus is to change the system. And, as it is primarily situational, it is concerned with the solution to problems in a specific context. Action Research conforms to what is generally called active research related to the need of education quality enhancement in a specific context [7].

This is why active participation is a key element in Action Research as it offers a valuable opportunity for teachers to be involved in research which is felt to be relevant. Furthermore, as it is grounded in the social context of the classroom and the institution, it may focus directly on issues and concerns which are significant. From this point of view, every teacher is a researcher because this method is not so much something that can be done in addition to teaching but something that can be integrated into it. As a result, during the research process, teachers become involved in thinking about their own teaching which ensures continued professional development and enhances competence.

Action Research can be defined as the study of a situation in order to enhance action in the community. In this particular case, our community is formed by:

- Students in the second year of the Bioengineering curriculum who are taking Vector Calculus and Differential Equations.
- Teachers with different graduate and postgraduate professional formation (engineers from different fields: electronics, electricity, chemistry, bioengineering, with postgraduate studies in diverse areas including informatics, and mathematics teachers with postgraduate studies in education).
- Teachers who carry out Vocational Orientation and Pedagogic Counseling, a service that was created in 2004 as part of the Academic Department, and teachers from the Languages and Social Sciences Department. These members of the group are specialists in Education and Languages. They are or have been in contact with the second year students on occasion of the counseling workshops for freshers, the English as a Foreign Language courses, and other courses to develop Reading and Writing skills.
- Advanced students who cooperate with the mathematics teachers.

The first step the research group took was to discuss and establish the goals of the project:

- To reflect on our teaching practice aiming at introducing principled change to the teaching-learning process in our mathematics course as part of the Bioengineering curriculum.
- To identify needs concerning our professional formation, thus ensuring continued professional development and enhancing competence in topics related to mathematics and their specific application to Bioengineering.
- To plan our continued professional development in pedagogical aspects that will offer tools to analyze and interpret the professional situations in which we act and make informed decisions accordingly.

- To foster interdisciplinary work among scholars belonging to the Mathematics, the Social Sciences and Languages Departments and the Vocational Orientation and Pedagogic Counseling Service of our faculty.
- To encourage the active participation of the students in Vector Calculus and Differential Equations classes in order to stimulate the development of a responsible attitude towards the learning process which will, eventually, generate an atmosphere for meaningful learning.
- To plan and implement activities that contribute towards the development of learning strategies the student will use in a conscious, reflective and effective manner.

IV. Design and Implementation

Action Research is structured in spiral cycles which are divided into four classic developmental phases: the initial exploration phase, the planning phase, the action phase and the reflection phase which generates a new research cycle [2].

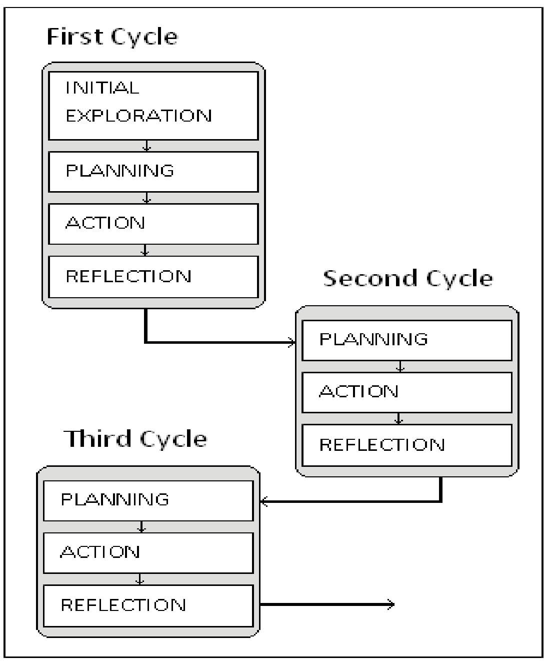

Figure 1. Action – Research Cycles

A. Initial exploration and conceptual frame of reference development.

The number of variables and circumstances that affect the teaching-learning process is significant. Thus, it is absolutely impossible to keep complete control over this complex whole. The first step in our project was to identify a problem and pose a specific question. We were confronted with the following dilemma: which aspects of the teaching-learning process are the most troublesome? We agreed that assessment is, doubtless, one of the burning issues in the process.

Traditionally, assessment in the Vector Calculus and Differential Equations courses has been carried out by means of term and final tests. The former have focused only on practical exercises while the latter deal with both practical and theoretical issues independently. The great number of students in our courses and Mathematics distinctive characteristics have led us to decide on administering written tests. Only on seldom occasions does the student sit an oral exam. We have noticed that students generally postpone study time to the last minute and the mistakes committed in the tests provide evidence of lack of conceptual and methodological comprehension. Furthermore, many students prepare for assessment solely through solving previous tests. This problem area led us to focus our enquiry on assessment.

Reflexion on our assessment techniques to brainstorm possible questions was the next step taken. Why do we assess this way? What do we assess? Which underlying rationale about teaching and learning Mathematics can be traced according to our assessment criteria? What other learning assessment criteria exist? Are there reports on recent research projects concerning these problems? These questions guided our research and helped to design a reference frame that served to redesign assessment.

According to Díaz Barriga an exam cannot improve the learning process by itself. The fundamental change must be carried out in the methodological strategies [8]. But those strategies cannot be designed without delving into the different principles that guide decision makers. The design of this conceptual frame was a long and complex process that brought about both agreement and disagreement among the members of the team with varied professional formation.

We finally agreed to synthesize criteria from Pedagogy, the didactics of Mathematics, and Cognitive Psychology that we have adopted as underlying principles that will inform the methodological changes and the redesign of learning assessment tools in our course:

- We adhere to a constructivist approach because it highlights the importance of understanding the knowledge construction process.
- In this particular context, our role changes from teachers to facilitators. That is, we do no longer merely transmit information to the class. Instead, the teacher must learn to act as a mediator that helps the student develop a set of cognitive skills that will enable the optimization of his / her reasoning skills (teaching to think) and favour mental strategies and processes awareness (metacogntion) in order to enhance learning (teaching about thinking) [9], [10], [11], [12]. Knowledge of metacognition was first developed in research on memory. Flavell (1971) first used the term metamemory, and later the term metacognition comprised metacognitive skills like monitoring and regulating cognitive processes [13] .
- We believe assessment is part of the teaching-learning process. It should promote learner autonomy and

responsibility. It is necessary to opt for assessment criteria that stimulate not only content learning, but also thinking processes and the development of metacognitive skills to assure students' awareness of the processes that have taken place, the mistakes committed, the learning strategies used and the difficulties encountered during the learning process [14]. In other words, our option is 'formative assessment' [15], [16], [17]. Moreover, apart from being a technical process, assessment is also a moral phenomenon and has an ideological and social component [18], [19].

B. Planning actions

From this point of view, we agree with Biggs in the sense that being a good teacher has much in common with being a good material designer. Good tasks should motivate the student and encourage him / her to reflect on his / her own learning process [20].

Once we had agreed upon our reference frame, without modifying neither the set amount of weekly face-to-face meetings for the courses (7 hours in the first semester and 8 hours in the second), nor the minimum contents for the subjects, the meetings took on a new whole meaning.

Traditionally, three weekly classroom activities were carried out in the following order: theoretical classes, discussion sessions, and practice sessions. The incorporation of assessment and metacognition activities was planned in the following way: The teacher presents the didactic unit in the theoretical classes by means of problematic situations to raise motivation among the students. Didactic questions are used to effectively diagnose the weak points concerning background knowledge.

When new concepts are presented, the teacher highlights the relationship between these and both prior knowledge and topics to be dealt with in future lessons or in other subjects in the curriculum. Definitions, properties and fundamental theorems are constructed collaboratively. A weekly study guide in which the goals of the unit are clearly set is presented to the students. It also includes a full bibliography and suggested readings[1], activities to be carried out during the discussion session and the weekly report to be discussed in the practice session.

During the discussion sessions some theoretical concepts presented in the theoretical class are dealt with more deeply by means of the analysis of selected demonstrations of formative value. This class aims at offering the student a space to carry out individual or group work using the suggested text and the weekly guide in order to clear up doubts and discuss mistakes while discussing demonstrations and examples. These activities also help to develop study strategies using Mathematics text books.

1 The texts used are: "Multivariable Calculus" by James Stewart, "Differential Equations with Boundary-Value Problems" by Dennis G. Zill and Michael R. Cullen.

This sequence of activities (see Table II) allows for a shift of the pendulum from a teacher-centered classroom to a more learner-centered one where students gain protagonism under the guidance of the teacher.

Classroom Activities	**Methodology**	**Assessment**
Theoretical Classes	Teacher presentation. Didactic interrogation.	Diagnostic assessment
Discussion Sessions	Group work with teacher participation. Discussion of demonstrations and examples. Integrative explanation carried out by the teacher.	Formative assessment Detection and correction of mistakes.
Practice Sessions	Students presentation of the weekly report. Integrative presentation carried out by the teacher.	Formative assessment. Self-assessment Peer-assessment

b. Activities.

The activities in the practice sessions are, thus, focused on the students. In furtherance of this, two types of activities are designed: the weekly report and the laboratory tasks.

What is the weekly report? In the theoretical class, the teacher presents the weekly guide in which the problems sections in the reference text are indicated. The sections correspond to the topics previously dealt with in the theoretical class and the discussion sessions. The selected exercises and problems are those that demand the application of different mathematical procedures and that are also related to other subject areas such as physics or biology. Between ten and fifteen problems are suggested, out of which five must be solved before each practice session using the text that was previously read in small groups and after having studied the corresponding theoretical background. A record of this activity must be kept in a weekly report in the following way: for each problem, the student must write the enunciation, the data provided, he / she must indicate its objective and explain the mathematical procedure(s) used to find the solution even if the attempt(s) failed.

At the end of each exercise, the student is asked to answer the following questionnaire: What new concepts or properties did I use? In what section and page of the textbook are they? Did I have to consult extra bibliography? What concepts from other subjects did I apply? Did I face any difficulties? Which ones? How did I try to solve them? Did I understand the concepts I used? Can I express them? What doubts do I still have?

The aim of this activity is to encourage a reflective attitude in the students, to promote the development of metacognition skills, to favour self-assessment habits and to promote learner autonomy. It enables us, teachers, to detect doubts and to act accordingly. As a result, the practice class is designed for students' full participation. They solve the problems presented in the weekly guide on the board, indicating the corresponding theoretical justification for each. If a student fails to solve any of the exercises, he / she is asked to mention the obstacles encountered. The teacher's task during this activity is to create an atmosphere of respect among students so that they can express their doubts without fear. This will favour both error correction and peer-correction, as well as making suggestions on the way the explanation was done. The teacher will do those exercises that present most difficulties to the group and will put forward others he / she considers appropriate for the students to solve in class individually or in groups in order to clarify concepts and methods.

The second activity is Computing Laboratory Tasks. Two integrative tasks are set for each semester. The teachers explain the rubrics of these tasks before presenting the corresponding topics. The students have the freedom to decide when to do them in a group of no more than three students. The only constraint is due date which coincides with the test corresponding to the same topic. In this way, carrying out the task will contribute towards learning the topics that will be assessed. These tasks also aim at taking advantage of software numeric, graphic, symbolic and calculus potentiality. To solve these, general mathematical procedures that contribute to the professional development of an engineer must be applied, i.e. modeling, graphic design, calculating, comparing, algorithmizing, solving, interpreting. Moreover, the student must apply definitions, formulate hypotheses, and refute linking theory to practice and to the applications proper to Bioengineering which are desirable in a second year student.

During the semester two integrative term tests that delve into theoretical and practical problems are carried out. One is administered mid-term and the other at the end of the semester. Vector Calculus and Differential Equations are courses whose accreditation is subject to the following conditions: a) presentation of 80 % of the reports carried out for the weekly practice session; b) marks corresponding to 80% (average) in the Laboratory Tasks; c) marks corresponding to 80% (average) in the term tests. Those students who fail to fulfill these requirements must sit a final exam (theory and practice).

C. Action

This planning was carried out for the first time during the development of Vector Calculus and Differential Equations courses in 2008. During the first semester, 66 students attended the course.

D. Reflection

To know the opinions of the students about the activities carried out during the course, the following survey was administered:

1) *Did you become engaged with this activity?* 85% of the students answered affirmatively.

2) *How much time during the week did you devote to the activity?* According to the answers, the average time devoted to carry out the activity was 4 hours (minimum 2 hours and maximum 10 hours).

3) *Have you formed a group to carry out and discuss the problems or do you prefer to work individually?* 36% of the students responded that they worked individually while 52% prefers to solve problems with a classmate.

4) *Have these activities helped you regulate your study time adequately? Yes?, No?, Explain.* 79% answered that the activities helped to "study the subject regularly which was positive when preparing for the term tests", "take advantage of the theoretical and practice classes", but some felt "it was an extra obligation to carry out the activities and assumed it as a burden". 21% explained that although they tried to complete the weekly activities at the beginning of the semester, they eventually could not sustain the rhythm. In some cases, they explicitly acknowledged that they needed to work at a slower pace than the one the subject syllabus imposes.

5) *How do you value this experience as a means to promote effective learning? Has it helped you detect and correct mistakes (conceptual and procedural ones)?* 85% of the students considered that the experience was useful and necessary because it helped them understand concepts and correct mistakes; 15% considered that is was not positive, especially because it did not respect individual rhythms as it is time consuming.

6) *Mention positive and negative aspects of this activity.* Some of the answers concerning positive aspects were: "I learnt how to study Mathematics better", "**we** worked more", "it helps to study day by day", "it helps to realize which are our doubts and clear them up in class", "it helped me realize that it's very advantageous to be constant", "it helps to study", "when we solved problems in previous years we were not obliged to think", "interesting and productive for the development of effective learning", "it helps me understand the topics", "it provided me with a way of studying". Students perceived the following pitfalls: "individual rhythms are not respected", "it's an extra burden", "it reduces time to study other subjects", "timetables to consult the teachers are insufficient", "there is no time to study a great variety of cases".

At the end of this first experience, the teachers in charge of the practice sessions expressed: "almost no students come to class without having tried to solve the problems", "the questions students ask are much more to the point", "gradual and continuous learning can be observed, some go deeper into the concepts studied in theoretical classes and discussion sessions". As regards the negative aspects and / or difficulties faced during the experience, some teachers said: "it is difficult to distribute time between monitoring individual work and group discussions to explain topics in which the whole group has problems", "the great amount of students per group makes personalized monitoring difficult".

Despite students' positive perception concerning the experience, we have noticed a strong resistance towards completing the questionnaire at the end of each weekly report problem. In many cases, this is due to the fact that many students believe it is "a waste of time", while others do not achieve to identify their difficulties. On occasions they say they have understood the concept, but the mistakes committed prove that it is quite the opposite. This is one of the aspects to be examined in future cycles of the project.

V. Results and Conclusions

The results of the 2008 academic year were good as only 11% of the 66 students who had enrolled in Vector Calculus had to retake the course, 30% passed the subject without sitting a final exam and 59% will sit the exam. At the end of the second semester (Differential Equations), 17% will have to retake the course, 43 % will sit a final exam, and 40% passed without having to sit it. As it was stated at the beginning of this paper, during the last five years 50% (average) of the students had to retake the course. This is why we consider that our project has brought about an opportunity for advancement. We should not forget, though, that both groups and context change year after year so it will be necessary to carry out adjustment cycle after cycle.

The analysis of the written material provided by the students and their weekly oral presentations are a source for obstacles detection. The lack of schemata to learn new topics is a constant problem. In many cases, the students themselves identify the topics that were not sufficiently dealt with in high school or during the first year of the university curriculum. Although some students offer resistance against completing the questionnaire in the weekly report, we still have the moment of the oral presentation or even a personal interview to complete that missing information.

We now have documented information which was regularly and systematically obtained that serves the purpose of working on different aspects of the teaching-learning process such as the articulation between the Mathematics Department chairs. As regards the Computing Laboratory tasks, students have responded with enthusiasm to these activities and the teachers have profited from the knowledge of other specialists teaching in the senior years such as the Biomechanics teacher who helped to find suitable and motivating problems for our students.

For the Mathematics teachers in the research team, it is an enriching experience to work together both with education professionals and Bioengineering specialists because their specific use of the language and their different points of view contribute towards our professional development. But this is only the beginning of a spiral process. New hypotheses have arisen to continue the process and to overcome the system's natural opposing forces

As we have tried to show in this paper, Action Research is a means for teachers to carry out both methodological and assessment changes to classroom practice according to the reference conceptual framework we designed and through which we can evaluate such modifications. In this sense, we consider it is a valuable tool for the professionalization of university undergraduate teaching.

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Developing and Evaluating a Game-Based Project Management Learning Platform

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Abstract—**Educators need to know how to motivate information-management (IM) students (i.e., future business practitioners) to learn and use project management, which can provide the practical skills necessary for IM professionals to analyze data and make decisions. This case designed a platform of game-based learning for IM students' studying based on course of project management. Using a sample of 54 sophomores in Taiwan, a modified TAM model, self-efficacy and flow experience in playfulness were examined using experimental design and causal analysis for learner's attitude and behavior. A knowledge test is conducted to inspect the learning performance with platform support. Test results present higher performance in posttest than in pretest. The empirical results show that self-efficacy has significant, positive effects on perceived usefulness; but not significance on perceived usefulness. Perceived ease of use is positive influence on perceived usefulness on flow experience. In addition, it was found that perceived usefulness and perceived ease of use, positively influence IM students' attitude to use game-based learning platform, and flow experience not significantly effect on attitude to use game-based learning platform, whereas attitude toward game-based learning platform has a significant, positive impact on behavioral intentions, and the behavioral intentions has positively significant impact on actual platform use based on course of project management. Both theoretical and practical implications are discussed in this paper.**

Keywords-game-based learning; project management; perceived usefulness; perceived ease of use; self-efficacy; flow experience

I. INTRODUCTION

One of the challenges of designing game for increasing the study interest is that of engaging IM students. Hosting a course should not just be about the individual teaching but also facilitating IM students' learning interest and experiences. Unfortunately, it seems that the individual teaching is used mainly as the information distribution channel that neglects the needs of IM students. To achieve IM students' attention, new ways to utilize game-based learning based on project program must be found. The use of technology alone does not motivate students that have lived in the midst of technology. Thus, learning situations and methods that engage learners must be created. One approach is to design the game-based learning platform based on project management in education. Computer games may create a new learning culture that corresponds better with undergraduate students' habits and interests.

Traditionally, games are equated with having fun. However, the fun factor is not the magic bullet in educational game design. The promise of educational games is to engage and motivate players through direct experiences with the game world. Games should provide possibilities for reflectively exploring phenomena, testing hypotheses and constructing objects. Games have been used in education primarily as tools for supporting the practice of factual information. The nature of action-based drill and practice games may lead to behavior, where players tend to try actions with no reflection on outcomes. In such games players may simply keep on experimenting with actions until the scores improve.

This paper emphasizes the need for integration of flow experience and self-efficacy, and modification of technology acceptance model (TAM) to be able to design meaningful and engaging educational games. These theories show that the self-efficacy, perceived usefulness, and perceived ease of use, flow experience, attitude, and behavior intention can predict students' behavior. The main purpose of this paper is to examine what perceived factors contribute to the game-based learning intention in order to generate an optimal learning experience for students maximize the impact of educational games.

II. LITERATURE REVIEW

Hasan [1] discussed extensions to previous research on computer self-efficacy (CSE) and systems acceptance by examining the impact of multilevel CSE on IS acceptance. Hus and Lu [2] applied the technology acceptance model (TAM) that incorporates social influences and flow experience as belief-related constructs to predict users' acceptance of on-line games. The results reveal that social norms, attitude, and flow experience explain about 80% of game playing. Kim [3] investigated the factors influencing the usage and acceptance of the mobile game in Korea, based on the extended version of TAM. Hasan [1] examined the effects of general and system-specific CSE on perceived ease of use, perceived usefulness, and behavioral intention to use a system based on TAM. Ha et al. [4] extended TAM to include an emotion variable and measured the moderating effects of gender, age, and prior experience on game adoption. Teo et al. [5] extends

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TAM framework, with subjective norm and facilitating conditions acting as external variables and showed that perceived usefulness, perceived ease of use and subjective norm were significant determinants of pre-service computer attitudes. Hsu et al. [6] provided the practical skills necessary for giving the students' study motivation. The empirical results showed that both computer attitude and statistical software self-efficacy have significant, positive effects on perceived usefulness. Moreover, Liu et al. [7] integrated framework: TAM, flow theory, and media richness theory on e-learning. This study revealed that perceived ease of use was a predictor of perceived usefulness; both the perceived usefulness and the attitude of the user were predictors of intention to use.

TAM is an adaptation of the theory of reasoned action (TRA) from psychology specifically tailored to model user acceptance of information technology. To provide an explanation and prediction of the determinants of IT usage, Davis [8] used the cost-benefit paradigm and self-efficacy theory to propose two influential beliefs: perceived usefulness and perceived ease of use. Perceived usefulness is defined as ''the degree to which a person believes that using a particular system would enhance his or her job performance'', and perceived ease of use as ''the degree to which a person believes that using a particular system would be free of effort''. According to TAM, the system usage is determined by individuals' attitudes toward using the system and perceived usefulness. Meanwhile, attitude toward using the system is jointly determined by perceived usefulness, perceived ease of use, self-efficacy, and flow experience. Hence, the hypotheses are stated as follows:

H1a: Self-efficacy will have a positive effect on perceived ease-of-use of a game-based project management learning platform.

H1b: Self-efficacy will have a positive effect on perceived usefulness of a game-based project management learning platform.

H2: Perceived usefulness will have a positive effect on attitude to use game-based project management learning platform.

H3: Perceived ease-of-use will have a positive effect on perceived usefulness of a game-based project management learning platform.

H4: Perceived ease-of-use will have a positive effect on behavioral intention to use game-based project management learning platform.

H5: Perceived ease-of-use is positively related to flow experience of game-based project management learning platform.

H6. Flow experience is positively related to attitude toward game-based project management learning platform.

H7. Flow is positively related to intention to use game-based project management learning platform.

H8: Attitude has a positive effect on the intention to use game-based project management learning platform.

H9: An individual's intention to use game-based project management learning platform will have a positive effect on that actual usage behavior.

Among the latter is a study of learner acceptance of game-based project management learning platform among students. We thus reviewed the definition of existing theoretical determinants, presented new constructs affecting the TAM, and hypothesized. Based on the theoretical review, an amended technology acceptance model as shown in figure 1 will be tested.

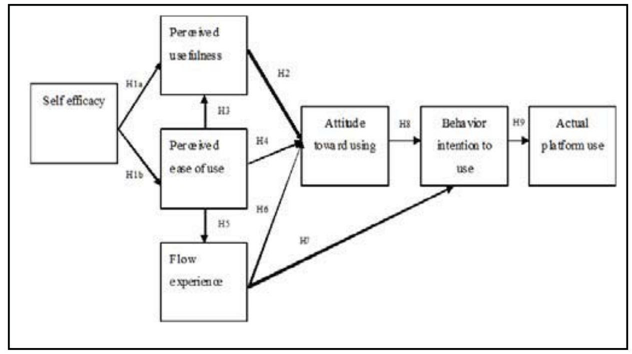

Figure 1. The Research Model of Game-based Project Management Learning Platform

III. RESEARCH METHODS

A. Course of Project Management

Project management based on challenging questions or problems is a complex task, through the student's design, problem solving, decision-making or action of research to give students a period of time engaged in self-related work, and the completion of a real product or report [9. 10]. Students in the project management can acquire new knowledge and skills through process of design, training courses and outcomes of products. As the number of aforementioned complex phases in project management, this study focuses the task of decision-making in project management as a lesson unit for teaching experiment.

B. Game-Based Project Management Learning Platform

In this study, game-based project management learning platform is to assist learners learning project management through the computer network game. The operational flow in the platform is divided into practice phase and exam phase. There are two game features were designed in two phases, including the reward / incentive mechanisms of practice phase and peer progress prompt of exam phase. In the practice phase, the more bonus points that learners earned from platform according to the earlier completion of their problem solving. Platform also popup message of encouragement to increase learner's confidence while they reply a wrong answer. In the exam phase, the platform announces the answer progress of each learner on other learner's screen to form a context to increase competitive play among learners. To contrast with the game-based project management learning platform, e-learning platform is usually not usually to emphasis on providing the functions like peer progress prompt, only to provide web-based materials learning.

C. Subjects

This study selected undergraduate students who initially to take the course of project management as the subjects. They all possess prior-knowledge of calculus and production management. They also attend the courses relating to the preliminary cost estimates, Calculus and Operation Management courses. In the teaching experiment, both pretest and posttest are conducted to verify the difference from learning platform use.

D. Procedure

It is a semester experiment. Subjects are first to take a pretest for getting attainment benchmark of learners in a classroom. An assistant then take the subjects into a laboratory for teaching experiment. Assistant first spends ten minutes to explain the purpose of lesson unit and practice way to the subjects. Next, they take forty minutes to practice exercises. During the practice, subjects are to use game-based project management learning platform to practice exercises. Finally, they take forty minutes to complete a knowledge test as posttest, and an attitude scaling are done for testing platform use.

E. Measurement

Measurement for self-efficacy was developed from the study of Compeau and Higgins [11] and Agarwal and Karahanna [12]. Measurements for perceived usefulness and perceived ease of use were adopted from the study of Hong et al. [13], with modifications of fit the game-based project management learning platform. Measurement for flow experience was built from the study of Novak et al [14]. Measurements for attitude and behavioral intention were adopted from Davis et al.'s study [15], and then measurement for actual system use was developed from the study of Venkatesh et al. [16]. The scales were slightly modified to suit the course of game-based project management. All items were measured using a 7-point-type scale with anchors from 'very strongly disagree' to 'very strongly agree'.

IV. RESULTS

In regard to the knowledge test, the posttest showed that subjects prevalently have a higher score than pretest. To test structural relationships, the hypothesized causal paths were estimated. The results of causal paths by structural modeling analysis are shown in the figure 2. Eight hypotheses were supported and two were rejected. The overall fit of the model is acceptable, since the goodness-of-fit statistics are satisfactory and acceptable. The results generally support the proposed model, illustrating the new roles of self-efficacy and flow experience in game-based project management learning platform. The specified relationship between perceived usefulness and perceived ease of use and self-efficacy was supported by the data, as indicated by a significant CR (critical ratio). The CR is a t-value obtained by dividing the estimate of the covariance by its standard error. According to Arbuckle [17], CR values larger than 1.96 and 2.32 are statistically significant at 0.05 and 0.01, respectively. Ease of use of game-based project management learning platform may be conducive to reaching a higher level of positive flow experience and user attitude. Flow experience was the most important determinant of user attitude and user intention for game-based project management learning platform. This reflects the significant effect of attitude on user intention. On the other hand, the effects of self-efficacy on perceived usefulness and flow experience on attitude were not supported by the results. There is a significant positive relationship between attitude and intention to use, and strong support for a positive relationship between intention to use and actual use behavior. The results imply that perceived usefulness/ease of use may influence attitude, which, in term, affects learners' use intention.

The model indicates that the variance in game-based project management learning platform explained, which is fairly high, given that numerous factors may affect acceptance of, and intention to use the game-based learning platform. The results show that the variance in individual intentions toward accepting the game-based project management learning platform can be explained by the experiment of self-efficacy, perceived ease of use, and flow experience, along with a relatively small control.

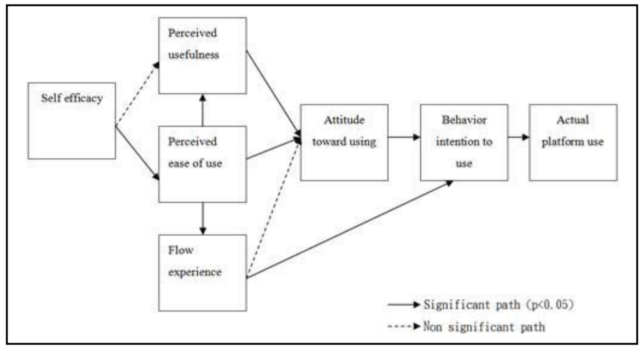

Figure 2. Results of structural modeling analysis

V. DISCUSSION AND CONCLUSION

The main purpose of this paper was to examine what factors would determine the learner acceptance of a game-based project management learning platform, an emerging innovative information system use the near future. We use the TAM to evaluate game-based learning usage based on project management. As prior research demonstrates, we find that self-efficacy is significant in using online game. The higher a person's self-efficacy, the less anxiety that person has in using a project management platform. As Compeau and Higgins [11] found, high self-efficacy can both relieve anxiety and increase positive influence in using a computer. Agarwal et al. [18] found that self-efficacy is more related to perceived ease of use than to perceived usefulness. Moreover, perceived ease of use on game-based project management learning platform, then, is now viewed as another determinant of flow experience, which in turn affects attitude and behavior intention to actual system use based on the course of project management [2].

The teachers who use this game-based project management learning platform should be aware of the importance of self-efficacy and flow experience applied on TAM. Interpersonal interaction among students creates a community in which education value can be created by improving learning interest and efficiency. When students use the game-based learning platform intensely, the interaction with other students will cause more to join in. Therefore, teachers should strive to attract opinion leaders or community builders to affect others to play this games-based project management learning platform through a normative effect. Moreover, through word-of-mouth communication or mass advertisements, teachers can accelerate network effects to achieve a perception of critical mass. The more students in this game-based learning, the more students-generated experience it is likely to exchange and thus the more users it will attract. This idea, called the dynamic loop, was found by Hagel and Armstrong [19] to yield increasing returns in a virtual community.

ACKNOWLEDGMENT

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Effectiveness of a Peer Mentoring Program in Engineering Education

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***Abstract*—The Mentoring Program of the *Escuela Técnica Superior de Ingenieros de Telecomunicación (ETSIT)* is intended to establish a mechanism based on peer mentoring provided by upper-class students *(Mentors)* to provide help, support, and resources to incoming first-year students *(Mentees)*. This paper focuses on the experience gained in the creation and development of the ETSIT Mentoring Program during five years. The evolution of the results obtained from the evaluation of various aspects of the ETSIT Mentoring Program, is also presented.**

Keywords-engineering education; engineering student retention; peer mentoring;

I. INTRODUCTION

Nowadays, with the number of students entering engineering degrees programs declining, it is important to focus efforts not only on attraction, but also on student retention. In this sense, student support during the transition to University is one of the main influences on whether a student stays or leaves. The challenges for someone transitioning from high school to university can be significant. These challenges can be even greater when the student is entering into engineering. As a support mechanism, successful *peer mentoring* can impact students' desire to remain in engineering and at the University [1].

The term *mentoring* refers to a supportive relationship that is characterized by constructive role-modeling, encouragement towards raised aspirations, and by positive reinforcement for the achievement of goals. *Peer mentoring* at University typically involves the support and guidance for new students from more experienced students within the same discipline. *Peer mentoring* is an important strategy for assisting first year students during their transition to University in order to minimize the attrition rates that are typically high at engineering degrees [2]. The benefits of mentoring programs are both personal and professional, offering the satisfaction of helping peers and increasing the confidence of experienced students.

This paper focuses on the experience gained in the creation and development of a peer mentoring program at *ETSIT (Escuela Técnica Superior de Ingenieros de Telecomunicación)* from the *University of Las Palmas de Gran Canaria (ULPGC)* during five years, giving a detailed description of the program, the logistics involved in its implementation, or the modifications introduced throughout its successive editions to improve their key elements – including the selection and training of *Mentors*, the organization of the *Mentor* and *Mentee* meetings, or the content of the reports that the *Mentors* have to complete after each meeting–. The evolution of the results obtained from the *Mentor* and *Mentee* satisfaction evaluation of various aspects of the ETSIT Mentoring Program, are also presented.

II. THE ETSIT MENTORING PROGRAM

The ETSIT Mentoring Program is intended to establish a mechanism based on peer mentoring provided by *Mentors* to provide help, support, and resources to incoming first-year students throughout their first semester at the university on a range of academic, social and administrative issues, under the supervision of *Teaching Tutors*. This peer mentoring program has been in existence since the academic year 2004-2005 and has proven to be successful promoting student involvement and enabling success in *Mentees'* academic, social, and personal endeavors, as soon as developing in *Mentors* professional and transferable skills to take into engineering practice. For the academic year 2006-2007, improvements based on feedback from the participants in previous editions were introduced in the ETSIT Mentoring Program to its actual form.

A. Organizational structure

The organizational structure of the ETSIT Mentoring Program is shown in Fig. 1. *Mentors* are in charge of group of a maximum of 6 *Mentees*, reporting to their *Teaching Tutor*, who is an experienced lecturer preferably teaching on the first year course. Each *Teaching Tutor* provides guidance and supervision to the *Mentors*. *Teaching Tutors* and *Mentors* report to the *Coordinator*, who has oversight of the program and is responsible for the assessment, holding the training and weekly mentor meetings, …

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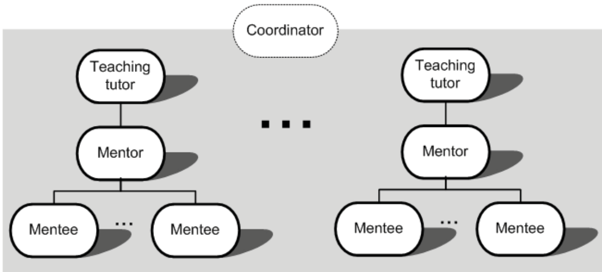

Figure 1. Organizational structure.

In addition, a technical committee coordinates the implementation of the different activities comprising the ETSIT Mentoring Program. This committee is composed by the Dean of the ETSIT, 3 lectures, and 2 undergraduate students. The *ETSIT Mentoring Program Technical Committee* meets at least two times throughout the duration of the program in order to select *Teaching Tutors* and *Mentors*, …

B. Recruiting and selection of Teaching Tutors & Mentors

The success of any mentoring program depends in large part on the skills of the *Mentors*. It is therefore important that care is taken when recruiting and selecting lecturers and students that will be involved in the mentoring program. The recruitment and selection of *Teaching Tutors* and *Mentors* commence at the end of the previous academic year, as *Mentors* need to be have been recruited and trained prior to the start of the academic year.

There are many strategies that can be used to make contact with the students whom *Mentors* will be selected. For the particular case of the ETSIT Mentoring Program, potential *Mentors* are contacted by publishing announcements on notice-boards, and by sending a mass email to students in later years of the degree. Potential *Teaching Tutors* are contacted by email.

Before agreeing to participate, potential *Mentors* are fully informed about the ETSIT Mentoring Program and about their role in it via an *information sheet* and an *information meeting*. The *information sheet* clearly identifies the aims, objectives and structure of the mentoring program, what will be expected from students who participate as *Mentors*, and especially how much time will be required of them. The *information sheet* also tells potential *Mentors* about the ongoing support they will receive. Finally, students are made aware of how their participation will be acknowledged. The *information meeting* is a session to which all students who have an interest in participating as *Mentors* are invited. The overriding purpose of such a meeting is to ensure that any student is fully informed about what is involved. The information meeting begins by welcoming and thanking all students for their interest in the mentoring program and having their attention drawn to the details that are provided on the *information sheet*.

Students who, having heard the detailed information, continue to believe they are able to make the necessary commitment, are asked to complete an application form. The application process consists of completing the application form with contact details, writing a short essay regarding the skills and experience they believe will enhance their ability to be effective *Mentors*, or the motivation for being involved in the mentoring program, and submitting a copy of their academic grades.

After the applications are received, the *ETSIT Mentoring Program Technical Committee* reviews the applications. The program faced several challenges when it began regarding how to organize the application and review process. Nowadays, students are selected mainly based on their academic progress and perceived interest in mentoring, since the importance of *Mentor'*s appreciation of the value of mentoring for the success of the program has been proved to be significant. In this sense, the technical committee members are familiar with most of the students who indicate that they would like to be *Mentors*, so it is not necessary asking them to attend any personal interview. The number of chosen *Mentors* depends on the available flexibility, that is, the number of applicants in relation to the number of *Mentors* required. *Teaching Tutors* are mainly selected based on their experience in mentoring, with special emphasis on the enrolment of lectures of first year subjects, since their participation in the ETSIT Mentoring Program has proven to be very important, as it allows closer links with lecturers and staff [3].

C. Training

Before meeting with the first year students, it is necessary to ensure that *Mentors* undergo appropriate training. The effectiveness of any mentoring program depends on the degree to which *Mentors* have the appropriate expertise, that is, both the skills and the knowledge. The greater their confidence in their skills and knowledge, the higher the likelihood that mentoring will be effective [4].

Training at the ETSIT Mentoring Program addresses issues related with the facilitation or conduct of the mentoring sessions, and others related to the content of the mentoring program. In this sense, *Mentors* have training in generic interpersonal communication skills, including building empathy, actively listening, or asking appropriate questions. Training identifies the strategies that *Mentors* might use for making their initial contact with their *Mentees*, for setting up the first meeting, and for running the first mentoring session. Interpersonal skills are put into practice in small group situations at the orientation and one-to-one in follow-up correspondence. In addition, *Mentors* are versed on campus resources, university activities, academic rules and resources, student associations, ETSIT organization, grants, exchange programs, …

D. Initial coordination session

The ETSIT Mentoring Program is established with a structure and relatively formal program to follow. The content of weekly mentoring sessions is agreed from *Coordinator*, *Teaching Tutors* and *Mentors* during an *initial coordination session* held before recruiting of *Mentees* and the start of the mentoring meetings. An outline of the topics that should be covered during the program of mentoring sessions is planned along with some suggestions for the week in which they must be addressed. This *initial coordination session* focuses on the content of the mentoring program, including the material, an identifying specific strategies and suggestive activities that might used for each of the topics or areas of material.

E. Recruiting of Mentees

One of the major challenges when the ETSIT Mentoring Program was implemented was how to inform incoming students about this opportunity. The chosen method is based on a flyer distributed during an announcement in a lecture in the first week of the course, ensuring that students are contacted early and in time for mentoring to begin from the second week of class. The flyer draws first year student's attention to the existence of the ETSIT Mentoring Program that is designed specifically for them. In addition, the information in the flyer includes the rationale for the mentoring program and its objectives, and briefly describes the expectations of participants in the mentoring program. Students are encouraged to attend a *welcoming session* during the second week of the course to learn more about the program and enroll in it.

F. Welcoming session

Before agreeing to participate, potential *Mentees* are fully informed about the ETSIT Mentoring Program, about what would be expected of them, and what they might hope to gain from being involved in it. The purpose of the *welcoming session* is mainly to ensure that any student interested in being a *Mentee* is fully informed about the mentoring program, and to mark off the start of the mentoring program for participants. The *welcoming meeting* begins with a welcome from the Dean of the ETSIT and covers a brief reiteration of the aims and objectives of the program, a comment about the efficacy of mentoring programs and the possible benefits of participating in mentoring, and a few remarks about being an effective *Mentee*.

Having provided students with the opportunity to ask questions about any aspects of the ETSIT Mentoring Program, those who decide to participate are asked to complete an application form. The form simply asks potential *Mentees* to record their contact details and about their permission that the information be provided to their *Mentor*, who will then make contact with them. Mentoring groups are formed just at the end of the *welcoming session*, providing the *Mentors* and *Mentees* with the opportunity to get to know each other before the start of the weekly mentoring sessions. *Mentors* are in charge of group of a maximum of 6 Mentees, with *Mentors* and *Mentees* being matched at random.

Figure 2. ETSIT Mentoring Program Portal.

G. Supporting tools

Once the mentoring program is underway –as soon as *Mentor* and *Mentees* groups are formed–, an intranet web-based portal is established by the *Coordinator*, shown in Fig. 2, as a supporting tool for *Teaching Tutors* and *Mentors*.

The ETSIT Mentoring Program Portal is exclusively available to the program participants and includes, among other, information related to the ETSIT Mentoring Program, a list of all the *Teaching Tutors*, *Mentors* and their *Mentees* with their contact details, and indicating the mentoring group to which they belong. In addition, a news forum is set up, so that there can be regular contact between the program *Coordinator* and all *Teaching Tutors* and *Mentors* who are involved in the program. Also, supporting information related to the topics proposed to be covered on the weekly mentoring sessions is provided. Finally, the web-based portal eases uploading and reviewing the reports being elaborated by the *Mentors* at the end of every weekly mentoring session.

H. Weekly mentoring sessions

The *Mentors* meet *Mentees* weekly during the first semester, beginning the second week of class. The first meeting typically lasts 45-50 minutes, with subsequent meetings typically lasting 30 minutes. At the first meeting, *Mentor* and *Mentees* get to know each other better and set up a weekly meeting time. It is important for the students to know they can terminate the relationship for any reason at any time.

Each week there are certain topics that *Mentors* will discuss with their *Mentees*, according to the planning agreed during the *initial coordination meeting*. These topics regard how to succeed in their first semester classes, being timed to provide the right information and support at the right time. With each meeting, *Mentees* gradually assume more responsibility for the weekly mentoring sessions. Main topics include academic rules, characteristics of subjects, structure of the first course, search for academic resources, student associations, ETSIT organization and services, … Other topics cover study habits, how to put a bad exam score in perspective, not repeating the same mistakes, organizational skills, dropping classes, exam survival, … *Mentors* discuss any issue of concern with the *Mentees*, not being limited to the topics to cover in any weekly mentoring session according to the planning agreed during the *initial coordination session*. In addition, *Mentees* complete three forms during the weekly sessions regarding previous knowledge of the degree and the motivation of the first year students for its election, their adaptation to the University, and the subjects covered on the first semester. The information obtained from these forms is used, i.e. to detect problems on the lectures of the subjects covered on the first semester of the degree. The second part of the first semester, *Mentees* have grown substantially, so topics cover some visits to research laboratories or telecommunication-related enterprises. Finally, the last meeting is held after the exams, in order for the *Mentors* to review the academic progress of the *Mentees*, being sensitive to students who appear to be at academic or personal risk.

In addition to weekly mentoring sessions, *Mentors* meet monthly to share experiences. Also, in order to involve *Teaching Tutors* with the *Mentor* and *Mentee*s weekly meetings, they are recommended to assist to some specific planned meetings covering critical topics for the first year students, allowing closer links with lecturers and supporting *Mentors*.

After each meeting with their *Mentees*, *Mentors* elaborate a report of the session and sends it to the *Coordinator* and their *Teaching Tutor*. This report is based on a template provided by the *Coordinator* of the mentoring program, including the meeting date and duration, along with the name of the assistants, the covered topics, and any comments or problems from the *Mentees*. Once fulfilled, *Mentors* upload each report using the web-based portal. Reports are available for the *Coordinator* and the *Teaching Tutors*.

III. ETSIT Mentoring Program Evaluation

The overriding objective of any evaluation process of a peer mentoring program is to determine the extent to which it has been effective [3]. The success of a mentoring program depends on how well it is able to assess its effectiveness, address any weakness and demonstrate that it is complaining established goals and objectives. However, evaluations of mentoring programs tend to exclusively assess *Mentees* satisfaction with a *Mentor*, with very few studies examining the impact of mentoring program on outcomes [5]. To ensure the quality and effectiveness of a mentoring program, it is necessary to develop a plan to measure program processes and expected outcomes, and create a process to reflect on and disseminate evaluation findings. To ensure the quality and effectiveness of a mentoring program, two different types of evaluation can be conducted depending on the purpose of the measurement [4]:

- *Process evaluations (formative evaluations)* focus on whether a program is being implemented as intended, how it is being experienced, and whether changes are needed to address any problems. Process evaluation is an ongoing data collection process that yields information about the successful activities and those needed to be determined. This information can help to improve the mentoring program. A well planned process evaluation is developed prior to the beginning of the mentoring program, and continues throughout the duration of the program.
- *Outcome evaluation (summative evaluations)* focus on what effects mentoring programs are having and help to determine objectively the benefits, costs, and necessary conditions to reach program objectives, and determine whether the mentoring program caused an improvement among the participants on certain aspects of interest.

Despite the importance of the information provided by the *Process evaluations* for self-monitoring and continuous improvement of program effectiveness, this paper will mainly focus on the issues and decisions involved in conducting an *Outcome evaluation* to assess the effectiveness of the ETSIT Mentoring Program in achieving pre-determined objectives. An *Outcome evaluation* implementation involves the specification of expected outcomes, the selection of appropriate instruments to measure outcomes, and the selection and implementation of an evaluation design.

A. Outcome evaluation

Outcome evaluation is a crucial part of any effective mentoring program as it provides information to increase its effectiveness through a feedback/continuous quality improvement process. *Outcome evaluations* of mentoring programs generally are of two major types [4]:

1) Single-group designs are the simplest and most common types of evaluation, since they are less intrusive and costly, and require less effort to complete. An example of a single-group evaluation is a survey completed by all participants at the completion of the program *(post test)* or before and after the program (*pre-post test*).

- *Post test.* Mentoring programs commonly use this design to determine how *Mentees* comply some aspects of interest at the completion of the mentoring program. *Post-test* evaluations can help determine whether the *Mentees* have achieved certain goals – according to the implicit or explicit objectives established during the planning of mentoring program–, or whether *Mentors* are satisfied with the mentoring program, among other issues.
- *Pre-post test.* Mentoring programs use this design to determine whether *Mentors* and *Mentees* actually improved during the mentoring program by comparing the results of a *pre test* and a *post test*. Even if *pre-post* evaluations can't indicate whether the mentoring program was responsible for the improvement, a *pre-post test* can be useful to detect differences within the group or to determine whether certain participant characteristics are related to achieving mentoring program goals.

2) *Comparison group designs* allow to determine whether the mentoring program is the cause of change in program participants, using controls to eliminate possible biases. An example of a comparison group evaluation is a *pre test* completed by all participants at the beginning of the program and a *post test* at the completion of the program to both the target mentoring group and a matched comparison group that does not receive mentoring. By including a comparison group it can be possible to isolate the effects of the program from the effecs of other plausible interpretation of change. However, this type of evaluation requires finding a comparison group that is sufficiently similar to the mentored group. In this sense, students who enlist in a mentoring program may differ –in terms of motivation, compliance, …– from those who do not enlist. Many mentoring programs are not willing to deliberately withhold their program from participants, mostly with the number of students entering engineering degrees programs declining.

The evaluation design adopted determines the confidence in the mentoring program to be the cause of improvements of potential in all participants. *Outcome Evaluation* of the ETSIT Mentoring Program is based on a *single-group* design with *post test*, since all first year students are invited to participate as potential *Mentees*. The outcomes are mainly measured using anonymous satisfaction surveys completed by *Teaching Tutors*, *Mentors* and *Mentees* after the fall meeting, as surveys of student perceptions provide just some information. These surveys have been elaborated as part of the activities of a mentoring network in university environments which includes most of the universities developing mentoring programs in Spain, including the University of Las Palmas de Gran Canaria (ULPGC) [6]. The elaboration of these common surveys has allowed the comparison of the results obtained from different universities on the same issues. The items on the survey cover different aspects of the ETSIT Mentoring Program, including *Personal Benefits*, *General Benefits*, *Development of the Program*, *Program Recommendation*, *Teaching Tutors/Mentors/Mentees evaluation*, and a *General Appraisal* of the mentoring program.

The results obtained for the 2008-2009 ETSIT Mentoring Program show that it is considered as helpful or very helpful by more than 90% of *Mentees*, 95% of *Mentors* and 88% of *Teaching Tutors*, with a general appraisal of 8.63, 9.12 and 9.37 (over 10), respectively. In addition, 70% of *Mentees* consider that ETSIT Mentoring Program has a positive influence on their academic, social, and personal endeavors, and more than 75% recommend to be enrolled in it, with an 83% willing to participate in the near future as *Mentors*.

However, as various issues covered through the implementation of mentoring programs are not directly used during the first semester at the university, and in many cases the incoming first-year students don't have an adequate temporal perspective to value all the aspects in which the mentoring program have influence, the ETSIT Mentoring Program also involves anonymous satisfaction surveys completed by *Mentees* after staying three years at the university in order to evaluate their perception about the effectiveness of the mentoring program on that period. Some of the results obtained from these surveys are shown in Fig. 3

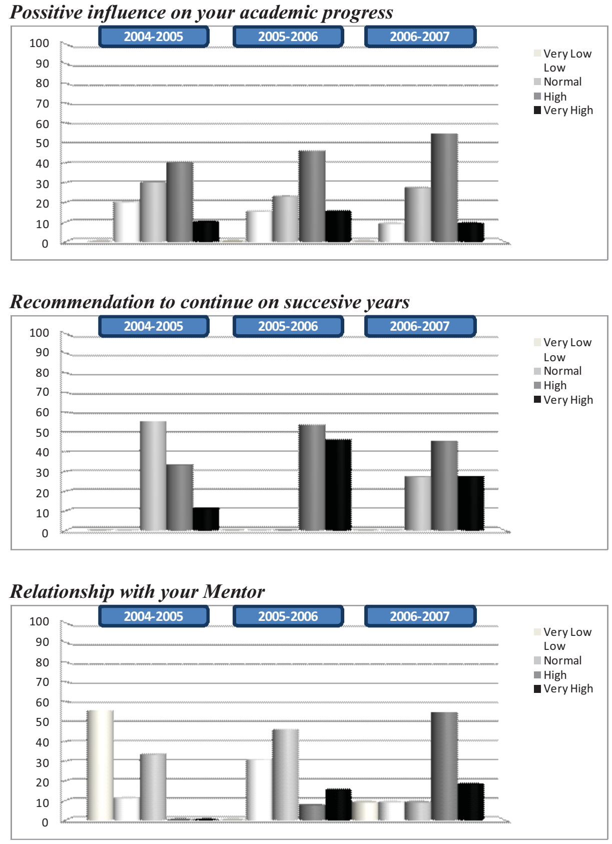

Figure 3. Results obtained from satisfaction surveys completed by *Mentees* after staying three years at the university.

for *Mentees* who participate in the ETSIT Mentoring Program along the academic years 2004-2005, 2005-2006 and 2006-2007, after staying three years at the university. From these results, 57% of students consider that ETSIT Mentoring Program had a high positive influence on their academic progress in mean, more than 72% highly recommend its continuity on successive years, and a 51% of students still continue the relationship with their *Mentors*.

However, satisfaction surveys often show that participants are at least somewhat satisfied, so results must be interpreted with some caution. High program satisfaction does not equal positive program outcomes, thus satisfaction surveys should be considered as just one part of an overall evaluation. In this sense, retention rate is tracked each academic year as a method of measuring retention of first-year students. In Table I, the overall first-year retention rates of *Mentees* for the last five academic years are shown. From these results, improvements introduced from the 2006-2007 academic year indicate that the ETSIT Mentoring Program successfully impacts retention.

TABLE I. OVERALL FIRST-YEAR RETENTION RATES OF MENTEES

Academic Year				
2004-2005	***2005-2006***	***2006-2007***	***2007-2008***	***2008-2009***
37%	32%	36%	56%	60%

In addition, a set of measurable indicators are being elaborated within the referred mentoring network in order to evaluate whether or not the mentoring program caused an improvement among the participants, including the degree to which the needs of the incoming first-year students are met, the skills gained by the *Mentors*, or the degree to which the university as a whole benefits from the mentoring program. These indicators will be used to improve *Outcome evaluation* of the ETSIT Mentoring Program at the current academic course 2009-2010, in order to verify the feasibility in collecting the required data and the relevancy of each indicator in determining the effectiveness of the mentoring program.

IV. CONCLUSIONS

The ETSIT Mentoring Program helps *Mentees* to develop an enhanced sense of student identity as an engineer, to become effectively integrated into the ETSIT, and to acquire the necessary skills to become independent. Regarding *Mentors*, the ETSIT Mentoring Program introduces them to skills in leadership, teamwork, problem solving, time-management, or communication, helping them get a leg up into professional practice. The effectiveness of this peer mentoring program can be attributed to several factors, including proper *Mentor* selection and training, weekly targeted meetings with *Mentees*, well timed information and mentee support, or the enrollment of lecturers teaching on the first year course.

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Session 08A Area 1: Learning Systems Platforms and Architectures - Virtual and Remote Labs

GILABVIR: Virtual Laboratories and Remote Laboratories in Engineering.

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Integration View of Web Labs and Learning Management Systems

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VirtuaLab, a Teaching/Learning System for 8 and 32 bits Microcontrollers

Manzanares-Bolea, Rodrigo; Martínez-Bejarano, Roberto; Sánchez-Reillo, Raul; Vázquez-Martínez, Juan

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Implementation of a virtual communications laboratory for e-Learning

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GILABVIR: Virtual Laboratories and Remote Laboratories in Engineering.

A Teaching Innovation Group of Interest.

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***Abstract*— GILABVIR (Grup d'Interès en Laboratoris Virtuals I Remots) is a recently created Virtual and Remote Laboratory Group of Interest at the UPC (Universitat Politècnica de Catalunya) and it is integrated in a more general teaching innovation project: RIMA [1], [2]. RIMA has been developed to promote research on the use of innovative learning methodologies applied to engineering education and it was specially created to assess in the new European higher education adaptation process.**

Keywords- Generic skill, digital campus, software platform, laboratory experiment.

I. Introduction

The GILABVIR Group is formed by high education faculty members who are involved within different laboratory courses, all of them characterized by the use of real and simulated experiments accessed through the moodle based UPC digital campus platform (ATENEA). The experiments in the different laboratory courses usually follow the next three steps sequence: 1.- The student designs the experiment and configures the parameters on-line, either at distance or in the computer classroom. 2.- The experiment is executed. 3.- The different results (numerical, graphical, images, etc.) are displayed and optionally recorded at the student computer and are also optionally recorded at the ATENEA server.

Up the date, there are nine laboratories integrated in GILABVIR and they are used in courses corresponding to curricula of: Electrical Engineering, Telecommunications Engineering, Computing Engineering, Industrial Engineering and Civil Engineering. Technical and didactic aspects of them have been collected and classified. The two main goals of this group are to detect common needs of the technical solutions of the different laboratories and design new educational methodologies that use virtual and remote laboratory based teaching activities.

The first goal is related to the implementation of a software application to join all the virtual and remote laboratories the UPC digital campus (moodle platform) and allow students execute experiments and teachers propose monitor and evaluate these experiments, instead of spending a lot of time developing access and activity management applications. A dedicated software tool (Moodle_LAB) is being programmed in order to control and monitor the access and execution of an experiment. With this option, professors can enable or disable the access to each experiment offered in each course and can also obtain information, individually for each student, about the timing, the configuration parameters or the obtained results. These data are used to evaluate the students. For most of the virtual and remote laboratory based learning activities, professors can obtain automatically a list of numerical results and records.

The second goal aims to improve the students learning outcomes, taking into account the design of the learning activities in the context of the European Higher Education Area, EHEA, both in specific knowledge and especially in generic skills.

Paper Outline—The rest of the paper, is organized in five sections. After an introductory section I, section II is dedicated to define virtual laboratories and remote laboratories, emphasizing the differences and comparative features between them when they are used for learning activities. The virtual and remote GILABVIR laboratories are described. The design and functionalities of the monitoring tool: Moodle_LAB are described in section III. In section IV innovative teaching methodologies based on these laboratories are presented and related to a generic skill list. Finally, the conclusions are described in section V.

II. Virtual and Remote Laboratories

The university education environment is becoming more diversified and interdisciplinary in the type of activities offered to students. Virtual and remote laboratories have been developed by combining experimentation, homework and use of information and communication technologies. In this context, when a student executes an experiment at distance, two different modalities must be distinguished: Virtual Laboratories and Remote Laboratories.

A Virtual Laboratory is defined as an interactive environment for designing and conducting simulated experiments. The experiment execution consists in running a program loaded in a remote server machine. To start this program the user accesses the server through a user interface. A software monitoring platform starts the simulator program. The program models some real experiment behavior, producing output signals, graphs and/or data when a set of input parameters is configured by the user.

A Remote Laboratory is defined as an interactive environment designed to allow users to remotely control real laboratories. A monitoring platform is installed in a remote server machine. To start the experiment the user accesses the monitoring application through a user interface and configures an input parameter set. After the experiment, measured data or

The group is supported by the ICE (Institut de Ciències de l'Educació) UPC including a financial aid from the 2009 - Educational Projects Budget.

signals are obtained and returned to the user through the monitoring application.

As it can be deduced from previous definitions, virtual laboratories and remote laboratories are extremely similar in the sequence of steps to follow when a practice is executed. Teaching methodologies based on these two kinds of laboratories are also very similar.

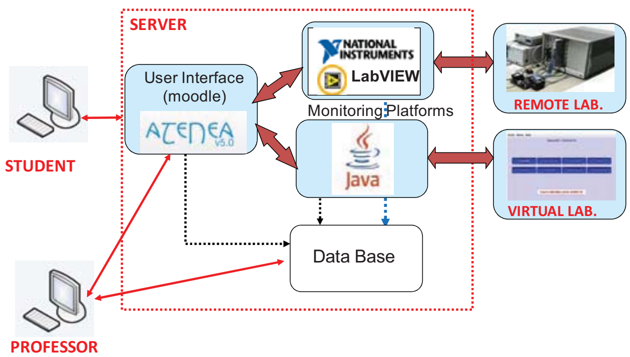

Figure 1. Remote laboratories and Virtual Laboratories are connected to the server through a software platform: Java or Labwiew. Atenea is the user interface (UPC Digital Campus).

Figure 1. shows a functional diagram including the elements that have a main role in this environment. Some advantages and disadvantages when comparing virtual and remote laboratories are displayed on table I.

TABLE I. ADVANTAGES AND DISADVANTAGES

Advantages	**Virtual**	**Remote**
Experimentation with real signals	NO	YES
Flexibility and configurability level	High	Medium
System registers user activity	YES	YES
Number of users simultaneously running the experiment.	Unlimited	1 user
Disadvantages	**Virtual**	**Remote**
Workstation booking system is necessary.	NO	YES
Software update is eventually necessary	YES	YES
Expensive	NO	YES

The GILABVIR group has been formed by faculty members who use virtual or remote laboratories in their teaching courses. Nine different projects directly related to nine different laboratories are currently grouped.

Virtual and remote laboratories that joined the GILABVIR initiative are described in the following list.

The group is supported by the ICE (Institut de Ciències de l'Educació) UPC including a financial aid from the 2009 - Educational Projects Budget.

A. Remote and virtual laboratories for mechatronics and enertronics students.

Different platforms have been designed to allow students to access the m re motely or virtua lly to complement the local laboratory sessions. The platforms are used in electrical engineering courses related to automation, mechatronics, motor control, renewable energy generation and power systems. Students program and supervise real systems as if they were working with real installations. This is done by using for example standard PLC (Programmable Logic Controller) programming software provided by the PLC manufacturers.

Remote laboratories include: Automation and motor control laboratory [5], Flexible manufacturing cell [6]. Power Quality laboratory, measurements of harmonics for different loads, power system laboratory, protection, fault detection and restoration of electrical power systems.

Virtual laboratories include: DC motor control laboratory, Hotel automation laboratory, Chemical process automation [7].

B. LAVICAD

The virtual laboratory of analog and digital communication systems is a useful tool to verify the performance of different communication systems and signal processing techniques, topics typically integrated in undergraduated courses of the curriculum of telecommunications engineering. The communication systems have been implemented and designed as Java applets and are free available. They can be run at the e-learning platform: comweb.upc.edu. The different communication systems present different levels of user interactivity and when students execute a system integrated in a comweb course, the obtained results can be supervised by the professor as an evaluation and assessment tool. From a pedagogical point of view, this laboratory has been created to facilitate the learning of certain matters, acting as a connection between the model of knowledge based on concepts and theories, and their practical understanding and experimentation.

C. Project: 62, an interactive tool to study discrete time signals and systems.

62 is an interactive tool written in JAVA that allows, first, to define discrete time signals and systems, and then to work with them. Signals, systems and operations are specified by means of menus or dialog windows without the need of knowledge of any programming language. One of these menus is devoted to specifying digital filters (FIR and IIR) both in the frequency and in time domains. The tool includes a graphic interface to show the sequences, their Fourier transform and the characterization of lineal invariant systems (frequency response, impulse response). The tool uses the A/D and D/A converters of the PC sound card. Thereby, the tool can generate and filter analogue signals in real time. 62 is part of the experimental framework designed for the students of discrete time signals and systems to carry out their practical training. This tool is freely available in [4].

D. iLabRS: Remote laboratory for Secondary Education.

iLabRS is built over a Modular platform to perform remote experiments in sensors and signal conditioning. It uses two experiment boards, which together with 3 additional boards allow doing currently 13 different practices. This remote Laboratory is aimed for Secondary Education students, to allow them to perform online real experiments, with remote access through Internet. The aim is triple: giving a tool to increase the experimentality in scientific and technological subjects, demonstrating the potential of the ICT's use and establishing a bridge between the secondary school and the university.

E. LEARN-SQL

LEARN-SQL is a system conforming to the IMS QTI specification that allows on-line learning and assessment of students on SQL and other database skills in an automatic, interactive, informative, scalable and extensible manner.

This tool facilitates the definition of virtual laboratories or remote questionnaires that are used by students of subjects to learn design and use of relational databases in the UPC.

LEARN-SQL is a tool whose main goal is helping in learning the use and design of relational databases in different subjects of schools of the UPC. More, specific goals are to:

- Provide the possibility to define virtual laboratories or remote questionnaires to be solved by the students at class or at home.
- Facilitate the participation of the students in its self-learning of database subjects.
- Provide students with valuable feedback, so that they can learn from their mistakes.
- Automatically evaluate the correctness of any SQL statement (queries, updates, stored procedures, triggers etc.) and other relational databases related exercises (Relational Algebra) with independence of the student solution.
- Help teachers define the questions or items in the remote questionnaires as well as allow them to review the solutions provided by the students.
- Adapt the subjects where it is used to the European Higher Education Area (EHEA) and to innovative education methodologies.

F. Circuit and Communications Systems Simulators

This virtual laboratory is still in construction.

The aim is to develop monitoring tools for homework based on running software simulators or remote laboratory experiments. The monitoring tool will automatically send a report to a moodle platform. It will be based in a Python module with functions to write ascii text, formatted text, results tables and figures in the report together with the answer to questions asked to the student.

This project is to be implemented in the following activities of the UPC "European Master of Research on Information and Communication Technologies":

Course: "Antennas for Communications" and "Waves and Systems". Activity: Modeling a WiFi system with intermediate repeater, including modulations and RF.

Course: "Electromagnetics Engineering". Activity: Analysis if a transmission line with impedance discontinuities using many different numerical methods in frequency or time domains. The results of different methods are compared in terms of accuracy and computational efficiency.

Course: "Design and Analysis of RF and Microwave Systems for Communication". Activity: Remote control of a network analyzer using the high-frequency circuit simulator ADS.

G. Modular platform to perform remote experiments in sensors and signal conditioning [8].

It is based on a custom acquisition board which includes a Ethernet capable microprocessor, so that every board has its own IP address. The connection of multiple boards to a switch allows the access to multiple experiments and/or to multiple replica of an experiment. Every board gives power supply and control signals to specific experiment boards that are connected to the control board in a sandwich structure. The signals are 4 A/D channels (16 bits), 2 D/A channels (14 bits), 8 control bits and a SPI bus. The experiment server runs specific applications made in LabView that control the experiments. Every application generates a remote panel that allows its use with a web browser. The link with the remote panel URL is placed among the course materials in the digital campus Atenea. This platform gives a certain degree of security, the user authentication and a basic record of the user activity. Four different experiment boards have been developed up to now, which allow performing 6 different laboratory activities around the sensor characterization and the set-up of conditioning and acquisition circuits. The use of the remote laboratory is focused as a complementary tool to add flexibility to the laboratory courses, mainly with the semi-distance students

H. VirtuaLab: remote workbench for instrumentation and sensors [9].

Remote laboratory based on a web server and a VXI modular instrumentation system connected to a circuit board with experiments and to a weather station. The access is made through a website (virtualab.upc.es) using a password. It only admits a single simultaneous user, who can use the resource during 20 minutes. Seven different laboratory activities can be carried out, from system identification and control, sensor calibration and remote control of instrumentation. In operation from 2003, the user interface was designed with the criterion of minimizing the data exchange and ensuring the system robustness. Because of this, the control applications in LabView that control the experiments are running in the server and they just exchange parameters and results with the user dialogues in the web pages.

I. rWLaB-Remote WaveLab

The goal of this laboratory is to convert an experimental setup (wave channel) into a platform for teaching, research and dissemination of knowledge using all the advantages offered by today's information technologies. Thus, we propose the creation of a knowledge portal based on experimentation with small-scale physical models with in the field of Maritime Engineering. The purpose of this portal will serve as the container of those remote and virtual laboratories that can be developed from this initiative. It is envisaged to provide the necessary content to the portal in order to, either through simulation, experimentation or study, achieve varying knowledge levels of methods and technologies employed in the experimental scale.

III. Connecting GILABVIR Projects to Moodle.

One of the main technical aims of the GILABVIR group is the connection of all the projects to the UPC digital campus. The UPC digital campus is a based moodle platform and it is called Atenea. In [3] some guidelines are proposed in order to connect virtual and remote laboratories to an educational platform.

Moodle_LAB is the application designed to connect all the at distance laboratories to the UPC digital campus. It is integrated by the connection module JLab and by the booking module.

A. Moodle Connection Module

The connection functionality allows the different at distance offered experiments can be run from a Moodle site. When an on-line experiment is invoked through the moodle platform there are some tasks that are identified to be performed in order to communicate the virtual and remote laboratories with the Moodle database to store practice results and then allow teachers view them.

The application that has been implemented is a new module for Moodle called JLab. JLab :

1. Centralize the management of the simulators that can be used in practices.

2. Allow laboratories to send the results to the server in order to be stored in the Moodle database.

3. Enable teachers to see the results of the practices from the portal and download them in Excel format.

The user enters in to the main portal using any browser. Then the user enters in a JLab practice of any of his courses.

On last page of this paper figure 3 shows the module operation process from the applet request to the results display. This is a communication protocol for a virtual java based laboratory, but the strategy is duplicated for any virtual or remote lab, using Java or Labview as software monitoring platforms.

1. The user enters in the main portal using any browser. Then the user enters in a JLab practice of any of his courses.
2. It shows the simulator applet using javascript embedded in view.php.
3. View.php obtains the id of the user connected, the id of the practice selected and a parameter that indicates if it is necessary to send the results to the server.
4. Applet is loaded.
5. Each stage of the applet, upon completion, generates an xml with the results.
6. This XML is sent to the server, the combeans.php file parses data and inserts them in the table mdl_jlab_results.
7. JLab also implements the report.php file which will show all users results of each practice.

Figure 2. shows the system architecture for at distance laboratories.

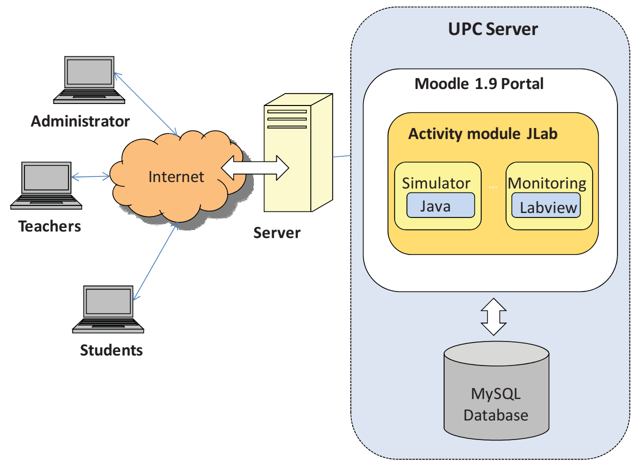

Figure 2. JLab – System Arquitecture.

Jlab module has been currently finished and it is being tested with a virtual laboratory (II.B) and with a remote laboratory (II.D). It is expected to connect all GILABVIR laboratories to Atenea campus on June 2010.

B. Moodle Booking Module

If the experiment is performed in a remote laboratory and the number of local workplaces is limited, a booking planning strategy becomes necessary. A dedicated moodle module is being designed to allow booking functionality and Jlab module coordinately work. The booking strategy defined for ours laboratories integrate:

- Students and teachers can book a workplace session some days in advance.
- A booked session can be modified or canceled
- The occupation time per session is configured by a laboratory administrator
- The dedicated moodle application assigns the workplaces to the booked sessions.
- A workplace inactivity detector releases the inactive workplaces and these are automatically available for other booked sessions.
- Teachers can supervise if a booked session is occupied by its owner.
- Laboratory responsible and teachers can periodically check the statistical books and the statistical use of the workplaces in the laboratory.

The Moodle booking module is currently being tested with a remote laboratory (II.D).

IV. ACADEMIC USE OF VIRTUAL AND REMOTE LABORATORIES

One of the main goals of the interest group is to share and improve the academic activities related with the use of virtual and remote laboratories. Two different aspects have been identified: the insertion strategies (how to use the virtual and remote labs within our subjects) and the learning methodology (what to do, evaluation, incidence in specific and generic skills, …).

After a survey within the group members, we can conclude that the virtual and remote labs are used both in classroom and remote activities. In addition to its remote use by the students, almost all labs are also used as demonstrators in classroom to support the teacher explanation and a half of them in laboratory sessions to enhance the in-situ activities. While one of the laboratories is used as an additional and independent activity and another as a substitutive of current laboratory activities, all others are used as complementary activities. Concerning the assessment, one half of the subjects including virtual or remote laboratories use them as voluntary issues while the other half specifies a given percentage of the mark. To perform the assessment, two of the involved subjects performed an automatic harvesting of results, a third one performed an automatic evaluation of the work and the remaining five performed a classical off-line gathering of reports.

Concerning the learning outcomes, the virtual and remote laboratories should contribute to improve the specific knowledge of the topics included in the respective subjects, but also to boost several generic skills. Among the mandatory skills defined by our University, the survey has shown that the use of virtual and remote laboratories can contribute to acquire the following skills: self-learning (8), effective use of learning resources (4), team work (3), innovation and entrepreneurship (1) and use of a foreign language (1). Additionally, the different schools can define other generic skills like "experimental behavior and instrumentation knowledge" or "engineering problems identification, modeling, formulation and solving". Most of them are also identified as targets of virtual and remote labs.

Several virtual and remote laboratories have born with a higher stress in their technical aspects than in their didactical aspects. An outcome of the Interest Group activity has been the recommendation of planning the virtual and remote laboratories as standard academic activities . That is, with a lifecycle that starts at the subject goals, defines a given learning activity, includes a deliverable that can be assessed and closes the cycle with an evaluation of the laboratory performance based on indicators. The learning activity should incorporate a form which, in addition to the technical content of the activity, gives information of all that aspects to the students. This includes the objectives and assessment criteria of the generic skills to be handled. As an example, table II describes the goals at three depth levels of the generic skill "engineering problems identification, modeling, formulation and solving". Each row in the table represents a different virtual or remote laboratory based activity that can be proposed to acquire the skill. Levels 1 and 2 are suitable for first and second years of an engineering degree and level 3 is proposed for third and fourth years. Goals at level 3 usually also serve to acquire more generic skills, as for instance "Cooperative Learning" and "Autonomous Learning".

V. CONCLUSIONS

The main aims of the GILABVIR group can be divided in two lines. As a result of detecting common needs of the technical solutions of the different laboratories, first line is related to the implementation of a software application to join all the virtual and remote laboratories the UPC digital campus Atenea moodle platform) and allow students execute experiments and teachers propose monitor and evaluate these experiments. The second main line is related to the design of new educational methodologies that use virtual and remote laboratory based teaching activities to improve the students learning outcomes both in specific knowledge and generic skills.

Concerning the learning effectiveness of web based experiments, in [10] a study is presented where their authors conclude that learning performance using dynamic media is significantly higher than those of the static textbook lesson, especially if the dynamic media can support learning when cognitive load and learners' mental representations. Furthermore, based on our experience, we can assure the learning effectiveness of dynamic resources doesn't depends on if they are offered by internet or in a laboratory classroom, but it is highly correlated with the teacher ability to choose the appropriate experiments to be made to work each subject or sequence of subjects in the program.

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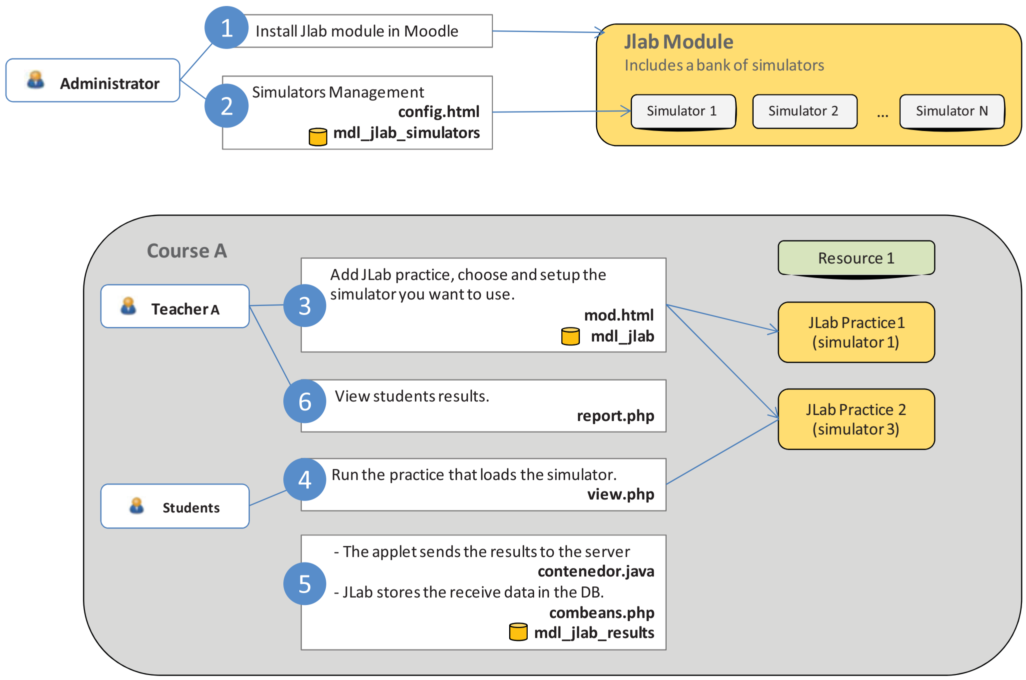

Figure 3. JLab – Module to communicate Moodle with simulators: Functional Diagram.

Table II: goals of the activities that should develop the generic skill "engineering problems identification, modeling, formulation and solving"

	Goals		
Virtual and remote laboratory uses	**Level 1** To perform a guided activity	**Level 2** To perform an open solution activity which includes a partial system or sub-system design	**Level 3** Design and assessment of a complex system
As a complementary activity of a theoretical exercise	To solve a guided theoretical exercise with the aid of a virtual or remote lab as a verification tool. Their configuration parameters are given by the exercise statement	To solve a non-guided theoretical exercise and to verify it with the aid of the lab. The lab configuration parameters are given by the exercise solution	Design of a new subsystem that becomes necessary to solve a given, complex problem
As a complementary activity of a laboratory practice	Use of the virtual or remote lab to help knowing the instrumentation, preparing a given in-situ practice or confirming their results	Use of the virtual or remote lab to perform non-guided activities that reinforce the in-situ lab activities and help analyzing their results	Design of a system or sub-system with the help of a virtual or remote laboratory. Validation in the in-situ lab.
As an independent, remote activity (e.g. remote access to a singular resource)	To perform a guided activity using a virtual or remote laboratory as a demonstrator	To interacting with a virtual or remote laboratory with modification of parameters	Design of a new building block for a virtual or remote laboratory

Integration View of Web Labs and Learning Management Systems

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***Abstract*—The integration of Learning Management Systems and specific learning support applications known as Web Labs (remote and virtual laboratories) are the target of a new wave of service-oriented applications devoted to improving on-line learning experiences.**

Nowadays these solution works in a separet way therefore the students teachers, administration must log in different systems, the are not reusing services, etc.

For these an other reasion in this paper we are focus in two topics. In one hand we describe a technique to present a web lab through a browser delivered by an LMS as a part of SCORM standard packaging. In other hand we describe a service-oriented architecture which allow integrating multiple LMSs (Moodle, .LRN, Claroline, etc.) with iLabs and multiples web an remote labs to supply the full functionality needed by educators

Keywords- e-learning; Learning management system; remote Labs, virtual labs, iLabarchitecture, e-learning standards; Web services.

I. Introduction

This paper discusses the need for merging several e-learning solutions into one. At present there are a great number of universities that are using blended learning or distance learning in parallel with traditional learning. In the case of distance learning, it is necessary to change and apply distance learning methods so that students achieve both theoretical and practical knowledge. To achieve this double goal, there are two new solutions particularly designed for distance learning [1]:

- A learning management system (LMS) is a software program that enables the display of theoretical content in an organized and controlled way. LMSs offer a set of features and services: user administration, e-learning standards (SCORM, IMS-QTI), content packing, etc.
- A web lab is a program that allows students to execute experiments remotely using a PC and an Internet connection. There are several ways to implement a web lab:
    - Software Lab. They are simulation programs and are executed locally on the student's computer. There is no collaborative work, and students do not work with real instruments or hardware.
    - Virtual Web Lab. These are simulation programs that use web resources. They permit students to collaborate during the execution of experiments.
    - Remote Lab. A remote lab allows the student to manipulate real instruments over the Internet during the run of an experiment.

Many universities are developing their own virtual and remote labs, but these efforts lack a unity of design, involve much custom development and present integration issues. There is little to no reuse of software between these efforts; each is developed from scratch. As one solution for this problem, the Massachusetts Institute of Technology has implemented the iLab Shared Architecture (ISA) [2-3] to facilitate the rapid development of new web labs and to provide a mechanism so that students from one university can use experiments and hardware instruments published from another.

While the ISA solves many problems, it does not offer the standard features supplied by learning management systems (e.g., chat, forums, learning modules). If you want these features in a current iLabs, you must program them into each lab's software. In this article we define a common architecture and middleware for adopting these typical LMS services as e-learning standards. We also illustrate the merger of theoretical and practical learning in a particular solution.

Thus, in this paper we will focus on two topics:

- We describe a technique to present a web lab through a browser delivered by an LMS as a part of SCORM standard packaging. The LMS will provide the web lab's communication, administration, and authentication tools. Of course, the lab can invoke the SCORM API so that the teacher can monitor the student's progress. When implemented as SCORM standard packages, web labs can be deployed in different LMSs such as Moodle, .LRN, Claroline, Sakai, etc.
- While the ISA provides an excellent management infrastructure for online labs, we argue that we need a service-oriented fusion of this architecture with general LMS services, compatible with multiple LMSs (Moodle, .LRN, Claroline, etc.) to supply the full functionality needed by educators.

II. LEARNING MANAGEMENT SYSTEMS (LMS)

A LMS is a software program that allows displaying theoretical content in an organized and controlled way. To do this, the most of LMS are designed using a common architecture, Fig. 1. that allows adding, deleting or modifying new functionalities.

The main elements in this architecture are:

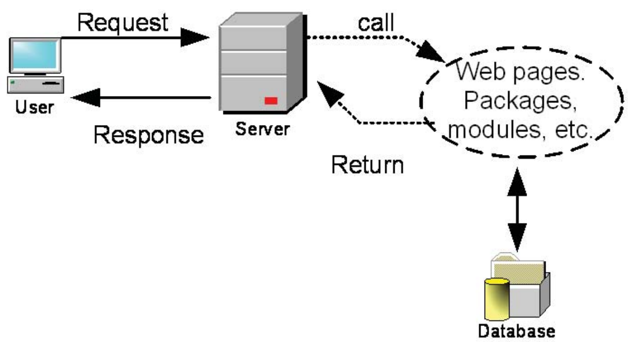

Figure 1. Architecture of a LMS.

- Database. This stores the information that the services are going to need and the information that will be displayed to user (administrators, teachers, students, etc.). Depend on the LMS that you are going to install and use, you will be able to work with mysql, oracle, postgres, etc.
- Modules, blocks, packages, etc. The structure of this modules or packages depends on the LMS. So how the programming language that you should use. For instance, if you are working in Moodle [4] you must use PHP to program. To sum up, these modules contain the logical of LMS services

  It is very important to mention that there are open source LMS as Moodle, DotLRN [5], Sakai [6], Claroline [7], etc. So that, a programmer could add new modules or modify standard services that are include in the standard installation of LMS.
- Web Server. All the LMS are installed along with a web server. This allows responding the user requests though Internet. Also, at the same that the others elements mentioned above, depending on the LMS with you are working, you have to install TOMCAT, APACHE, etc.

Once, we have known how a basic LMS architecture is. We are going to enumerate several of most important features and services that a LMS offers:

- Administration. It must be able to manage user registrations, roles, assign tutors, user payments, etc
- Content packing. It organizes the content in a hierarchical structure and sets up a mechanism to swap content between different learning management systems. To do it, it's usually used the specification IMS content packaging or the specification SCORM (Shareable Courseware Object Reference Model).
- Synchronous and asynchronous Communication Tools. It must allow collaborative work. So that they can share information, opinions and experiences.
- Knowledge evaluation. The tutors and teachers must be able to evaluate the student's progress. Also the students can do test where they can see their progress. To do it, it's possible to use the specification IMS QTI (Question and Test Interoperability).
- Tracking user. This feature should provide information user with teacher about that difficulties and problems have been found in the course by the students for the course term.

So, we have a tool that offers a set of features and services to display theoretical content in an organized and controlled way. As well as using e-learning standards like SCORM, IMS-QTI, etc.

III. SOFTWARE, WEB, REMOTE LAB AND ILAB

In many distance learning o blended learning courses, besides displaying theoretical knowledge by LMSs, is needed that the students acquire skills and practical knowledge. This and other reasons (the students are be able to carry out their experiment 24 hour by day and 365 day in a year, etc.) have given risen to design and create software, web and remote labs [8].

In this section we are going a brief description each one of these labs and one solution called iLab that was developed by the Massachusetts Institute of Technology to facilitate the rapid development of new web labs and to provide a mechanism so that students from one university can use experiments and hardware instruments published from another.

- Software Labs

  They are based on software programs that are being executed in the student's computer, Fig. 2.

  The student's computer must have the hardware and software requirements and an Internet connection it is not required.

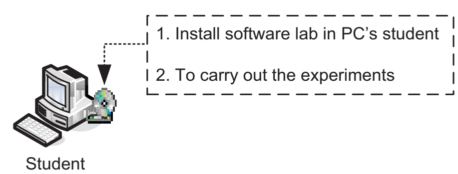

Figure 2. Software Lab.

Some of the main problems of theses labs are:

- Lack of collaborative tools
- Version problems, students have a lot of version of same labs. To solve it, the software labs allow the students to update the software using an Internet connection, Fig. 3.

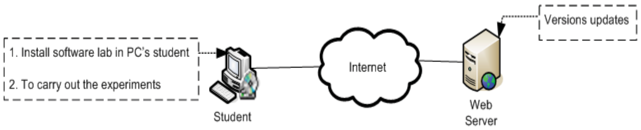

Figure 3. Software Lab with Internet Connection.

- Web Lab. These are simulation programs that use web resources. They permit students to collaborate during the execution of experiments, Fig. 4.

  The main problem is that students don´t manipulate real instruments to carry out his experiments.

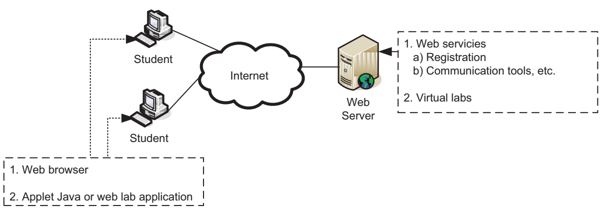

Figure 4. Web Lab.

- Remote Lab. These are simulation programs that use web resources. They permit students to collaborate during the execution of experiments, Fig 5.

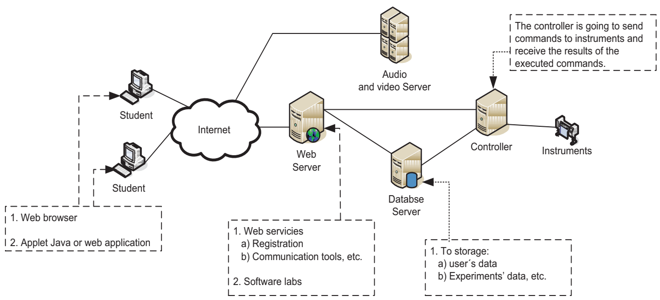

Figure 5. Web Lab.

Once we have described briefly what are software, web and remote labs. We are going to talk about the main problem that appeared. Many universities and organizations started developing their own virtual and remote labs, but these efforts lack a unity of design, involve much custom development and present integration issues. There is little to no reuse of software between these efforts; each is developed from scratch. For this reason, the Massachusetts Institute of Technology implemented iLab Shared Architecture (ISA) to facilitate the rapid development of new web labs and to provide a mechanism so that students from one university can use experiments and hardware instruments published from another.

To do this MIT divide the experiments according to the type interaction between user and lab. As a result of this, MIT has designed two architectures:

- Architecture based on batched experiments, Fig. 6.

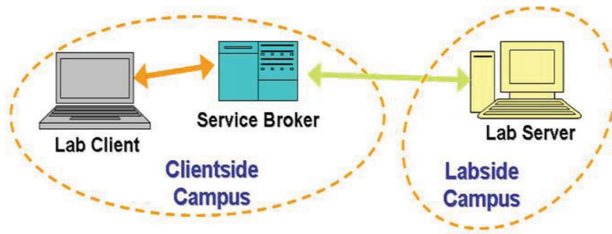

Figure 6. Topology of a batched experiment based on the iLab shared.

- Architecture based on interactive experiments where user and labs must establish a direct communication, Fig. 7.

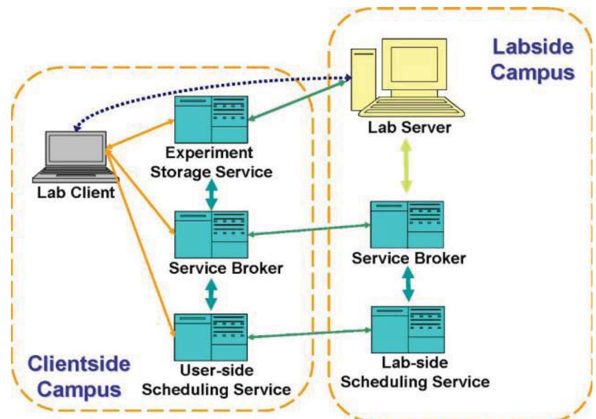

Figure 7. Topology of a interactive experiment based on the iLab shared.

So, ISA supports batch and interactive experiments. But, as well as, ISA allows being installed in every university or organization and therefore a student of one university could log in the system and using the web and remote labs from other universities.

While the ISA solves many problems, it does not offer the standard features supplied by learning management systems (e.g., chat, forums, learning modules). If you want these features in a current iLabs, you must program them into each lab's software.

So, imaging two universities, both of them want to create the same electronic remote laboratory and as well as theses universities want the laboratory provide one set of features, as: authentication, forums, chat, etc. To do this both of these universities must facing with the following challenges and disadvantages:

- Everyone should:
  - Defining and design one architecture. And probably the chosen architecture will be different.

- Programming and implementing the lab. Depend on the chosen architecture will be used different programming languages.

This provoked that the user from different universities needed different ways to log in and work with the system and therefore it is impossible to share labs. Due to this, appears ISA.

- Also, everyone should create the services that the laboratory needs as: forums, chats, storage area, etc. This is a problem, because by every lab we have to create, we must programme the same services one and other time. And therefore , the universities are wasting their time, personal and efforts in doing the same thing all the time, Fig 8.

To solve this and other problems as the integrating between both solutions (LMS and web, remote labs) we are defining and developing a common architecture and middleware for that the labs could use the LMS services and e-learning standards, Fig 9. And therefore, reuse services.

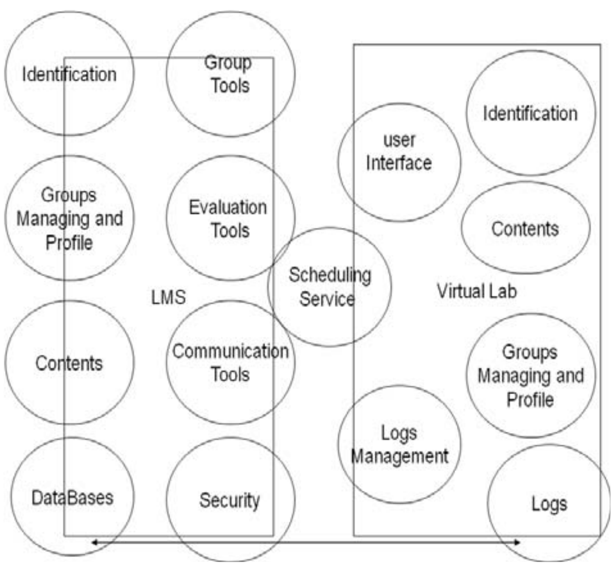

Figure 8. Duplicating services.

In the next sections also illustrate the merger of theoretical and practical learning in a particular solution. Thus, in this paper we will focus on two topics:

- We describe a technique to present a web lab through a browser delivered by an LMS as a part of SCORM standard packaging. The LMS will provide the web lab's communication, administration, and authentication tools. Of course, the lab can invoke the SCORM API so that the teacher can monitor the student's progress. When implemented as SCORM standard packages, web labs can be deployed in different LMSs such as Moodle, .LRN, Claroline, Sakai, etc.
- While the ISA provides an excellent management infrastructure for online labs, we argue that we need a service-oriented fusion of this architecture with general LMS services, compatible with multiple LMSs (Moodle, .LRN, Claroline, etc.) to supply the full functionality needed by educators.

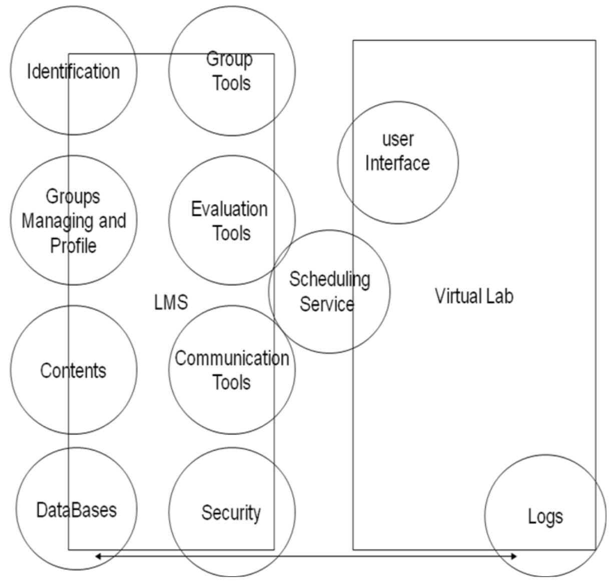

Figure 9. Reusing services.

IV. SCORM AND LMS

A Great number of Learning Management Systems support several e-learning standards as: IMS_QTI, IMS-LD, SCORM, etc. Every one of these has a different utility, for instance IMS-QTI is a specification for a metalanguage which enables the modeling of learning processes. In this section we are going to focus on e-learning standard called Sharable Content Object Reference Model (SCORM) [9-10].

SCORM content packaging provides a consistent form for describing content structures, learning content, the metadata that describes the various components of the content structures and sequencing and navigation rules.

This facilitates searching and discovering content packages and their resources.

How it is mentioned above SCORM documentation version 2004 describes a set of features of a content package as:

- Content Packaging: describes the SCORM components used to build a learning experience from learning resources. So, a package SCORM is composed of assets, sharable content objects (SCOs), activities, a content organization and content aggregations, Fig. 10.

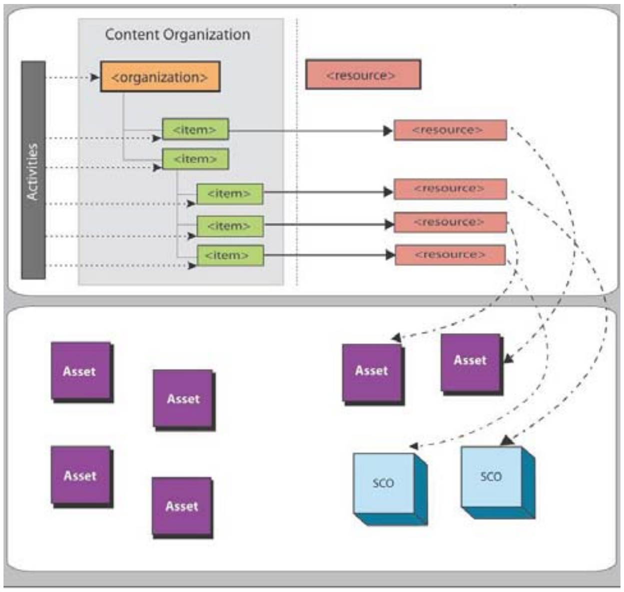

Figure 10. Content aggregation.

- Assets are an electronic representation of media, such as text, images, sound, assessment objects or any other piece of data that can be rendered by a Web client and presented to a learner.
- A SCO is a collection of one or more assets. The only difference between a SCO and an asset is that the SCO communicates with an LMS using the Institute for Electrical and Electronics Engineers (IEEE) ECMAScript.
- A learning activity may provide a learning resource (SCO or asset) to the learner or it may be composed of several sub-activities.
- A content organization is a representation or map that defines the intended use of the content through structured units of instruction (activities).
- Content aggregation can be used to describe the action or process of composing a set of functionally related content objects so that the set can be applied in a learning experience.

These packages are saved in a zip file. This file contains among other files, a description of package in XML, named imsmanifest.xml and the physical file of resources called

- The SCORM Run-Time Environment, Fig. 11. In this "book" is described:
  - Content launch process. LMS must load the SCORM when the user perform a request.
  - Standardized communication between content and LMSs. To do this, it uses an API
  - Standardized data model elements used for passing information relevant to the learner's experience with the content.

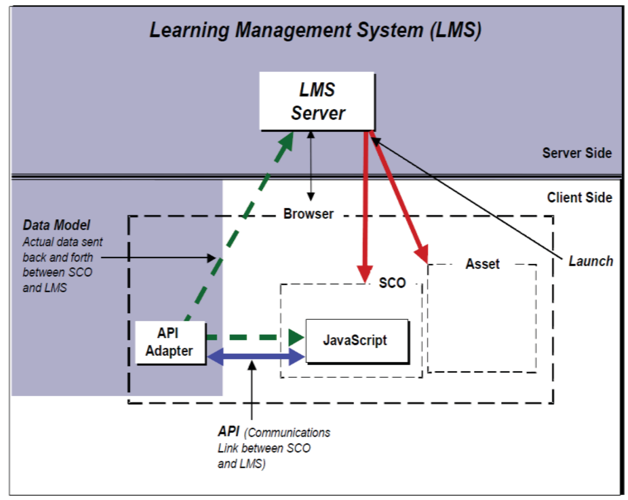

Figure 11. Scorm Run-time eviroment.

- Sequencing and Navigation: Descriptions and requirements for defining sequencing and navigation information.

  Nowadays there are several versions of SCORM v1.1, 1.2, 2004 and not all this version supports sequencing and navigation.

So, if a teacher or e-learning designer creates a SCORM package using these specifications then he could install it in all the LMS that support that SCORM version, reusing content and services.

V. PACKING WEB LAB IN SCORM

In the previous section we have read how a SCORM is composed and how we can communicate this SCORM with the LMS using an API. Now we are going to explain how we could use a web lab into a SCORM and therefore how we could reusing the LMS services and install this package in different LMS that are SCORM compliant.

Nowadays you don´t need program to create a SCORM package, only if you want to use the API for communicating LMS and SCORM. In this case you have to include in SCOs one o several javascript file, for instance:

- APIWrapper.js whose purpose is in wrapping the calls to the API is to provide a consistent means of finding the LMS API implementation within the window hierarchy and to validate that the data being exchanged via the API conforms to the defined CMI data types.
- SCOFunctions.js contains functions encapsulate actions that are taken when the user navigates between SCOs, or exits the Lesson.

Once you include these files in an html page or other SCO. You could use the functions that they have implemented to communicate with the API implemented in the LMS, Fig. 12.

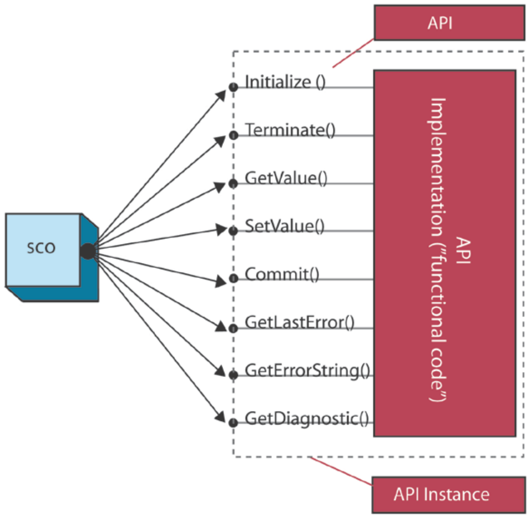

Figure 12. API.

It is very important to tell that when you create a web o remote labs you can use programming languages that don´t allow embedding JavaScript code, in this case we can integrate this lab in and *iframe* of a web page and in this page adds API functions to establish a communication with the LMS. The main problem is that the lab couldn´t communicate directly with the LMS. At this moment there are several projects to implement this API with web services.

So, the first thing that we have to do is to collect the resources that are going to composed the SCORM (html pages, images, etc.) and include the javascript files, that implement the API functions such as initializing the connection, exchanging information between SCO and LMS and finishing the connection, in the SCO that we want to communicate with the LMS. Later we have to establish an organization of every one of the resources to compose aggregation content.

Nowadays there is a great number of tools (free or commercial) allowing creating SCORM packages in a graphical way. So the teacher o learning designer, who don´t know about XML, can create their own SCORM packages without problems. Some of these free tools are:

- Reload, Reusable eLearning Object Authoring and Delivery.
- Couselab, is a free program but is not open source.
- eXe OPEN SOURCE SCORM Development Package

For this small example of weblab SCORM we have used Reload [11] and have include a web page named pag1.htm that include an *iframe* whit a URL of web lab in, Fig. 13. Of course you can include a web page hierarchy where you explain how the web lab works, the experiments that user can carry out, etc.

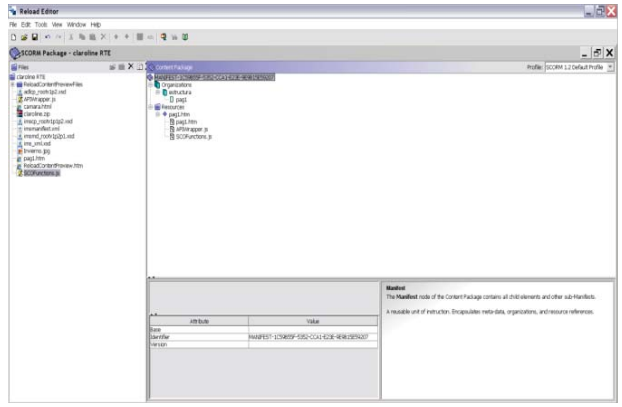

Figure 13. SCORM package created with Reload.

Once you save it, you could install this package in every e-learning platform that supports the same SCORM version that you have created. In the figure 14, we can see the result of installing this SCORM in Moodle.

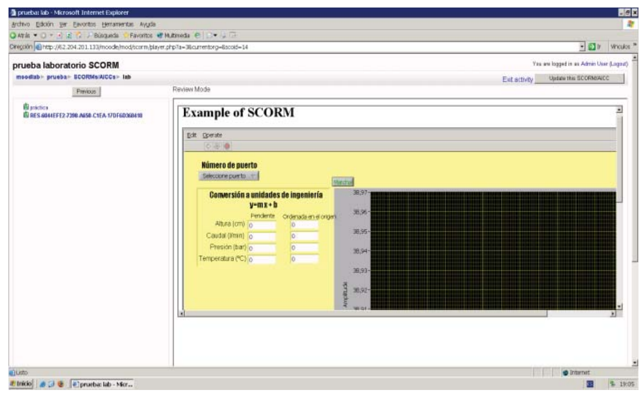

Figure 14. SCORM installed in Moodle.

Besides of creating an SCORM with a weblab, information about the experiment, etc and can use it in different LMSs (reusing). Also the user could use the LMS services as: Chats, Forums, Storage area, etc without having to be written a code line by lab programmer.

We have mentioned the problem in which code of web lab doesn´t allow embedding JavaScript and therefore there is no direct communication between web lab and LMS. To solve this and other problem as:

- What happen if the URL of web lab changes
- If we have several identical web labs and one this less busy than other (load balancing)
- If we simply want that web lab send information in a directly way
- Etc.

To solve this and other problems, we are working in a middleware for merging and managing both LMSs and web, remote labs in one.

VI. NEW MIDDLEWARE

In his section we are going to focus on a middleware and architecture to manage and integrate both solutions in one, Fig 15.

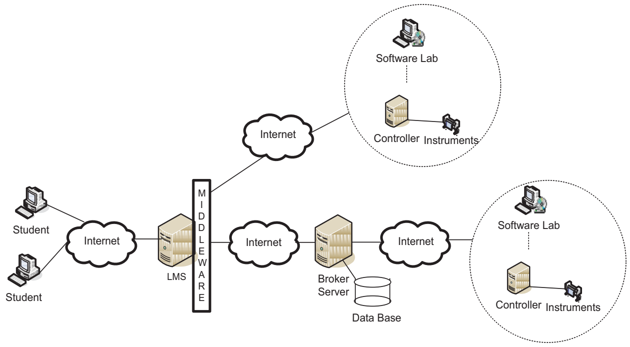

Figure 15. Integration LMS, iLabs and Virtual Labs.

To design this architecture we have to consider several ideas that have been mentioned in the previous sections:

1. The most of the LMS is composed by data base, a logical programming structure (modules, blocks, packages, etc.) and Web servers. So, we can design a module or package that use a database where is stored information about the laboratories, experiments, the pair lab-course, etc.

   Therefore if we design a module in an open source LMS as Moodle, this module could be installed in every server that contains an instance of Moodle. And the same if we create a package in .LRN or in other open source LMS as claroline, sakai, etc.
2. The iLab Shared Architecture (ISA) to facilitate the rapid development of new web labs and to provide a mechanism so that students from one university can use experiments and hardware instruments published from another.
3. There are other laboratories that only need be connected with a URL, with some information through of URL or other type of connection.
4. Both LMS as Web and remote labs need be displayed through Internet and by the way they use Web servers.

If we consider these ideas, the first thing that we should decide was what type of communication through Internet allows establishing a good communication among different systems and as well as provide several features as: scalability, loose coupling, etc. One of the best solutions that fulfil with these requirements is Service Oriented Architecture (SOA), Fig. 16.

As you can see in the figure 16, SOA [12-15]is based on services, to avoid the duplicating the services, the services providers publish information about the web service. The web service clients can search for the web services directory, if there are any web services that carry out the actions that the client need. If it is found the client bin and invoke the web service that is located in the provider.

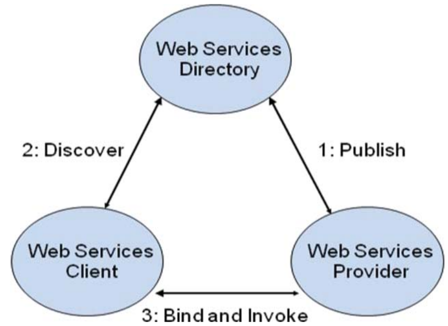

Figure 16. SOA.

All this process used several standards as:

- Web Services Description Language (WSDL) is an XML format for describing network services as a set of endpoints operating on messages containing either document-oriented or procedure-oriented information. The operations and messages are described abstractly, and then bound to a concrete network protocol and message format to define an endpoint.
- Discovery and Integration (UDDI) is a directory service where providers can register and clients search for Web services.
- Simple Object Access Protocol (SOAP) is a lightweight protocol for exchange of information in a decentralized, distributed environment. It is an XML based protocol that consists of three parts: an envelope that defines a framework for describing what is in a message and how to process it, a set of encoding rules for expressing instances of application-defined datatypes, and a convention for representing remote procedure calls and responses.

One part of SOA is the infrastructure that allows you to use services in a productive system. This is usually called the enterprise service bus (ESB), Fig. 17. The responsibilities of ESB involve:

- Providing connectivity
- Data transformation
- (intelligent) routing
- Dealing with security
- Dealing with reliability
- Service management
- Monitoring and logging

Therefore, this middleware establishes a way to communicate heterogeneous systems (such as old systems and new systems), provides a set of features as routing, security, etc. And it is based on Standards as WSDL [16], UDDI [17], SOAP [18], etc.

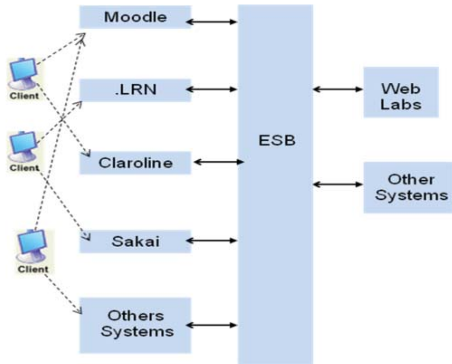

Figure 17. ESB.

VII. LMS (MODULE, PACKAGES BLOCKS, ETC.)

One of the first steps to define and design the architecture mentioned in the last section is to create LMS architecture. So, we have read that an open source LMS is composed by database, a logical programming structure (packages, modules, blocks, etc.) and web server. If we communicate and programme this element we can create an architecture based on services, Fig. 18.

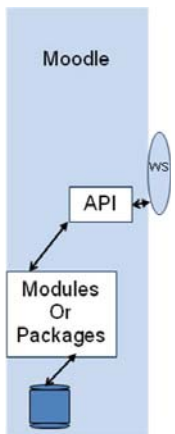

Figure 18. Middleware to connect a client with open source LMS as Moodle

At this point, we are talking about the creating of one .LRN package and a Moodle module to connect web and remote labs.

A. .LRN package:

We have defined and programmed a package for every .LRN administrator can create an area where connect a web or remote labs. To do this area we have created a package with the followed elements:

- A set of table associates to .LRN database (oracle or postgres) to store the created laboratory, the experiments that you are going to do, the way of connection between .LRN and web or remote lab, etc.
- A Logical programming (using Tool Command Language TCL) to exchange information between user and LMS, etc.
- And a user interface (ADP or HTML files).

Once the package has been installed in the .LRN the administrator could create all the areas that we need. This area is composed by, Fig. 19:

- A navigation menu where we can find services as:
  - Calendar
  - Asynchronous communication (forums, etc.)
  - Synchronous communication (chats, etc.)
  - Experiment area where are stored user manual, texts about the experiment, etc.
  - And area to display the remote labs and where the students can be work with it.

Figure 19. .LRN package.

B. Moodle Module:

To create a lab module in its first version we have carry out the next step:

1- We have created a set of table and have related them with Moodle database. To create this table we have used a XML file called intall.xml that uses Moddle to allow generating these tables with independence of the type of database that you install in Moodle (mysql, oracle, etc.).

2- We also modify the administration site for allowing that the administrator is able to add, modify and delete the labs or server broker (in case of iLab) and the way of connection of these, Fig. 20.

3- Later we have created te PHP file that provide of tle logical of module, as:

   a. Add a laboratory to a course.
   b. To Call connection services
   c. To store information in the tables of module
   d. Etc.

As a result of this a teacher could add every lab which has been inserted, using Administration site, in a course, Fig 21.

If we click on the created link then the students log in the web lab directly. Of course this is a first version so that we connect with web labs that require the username and password through URL. We are working in designing and implementation the web services into LMS.

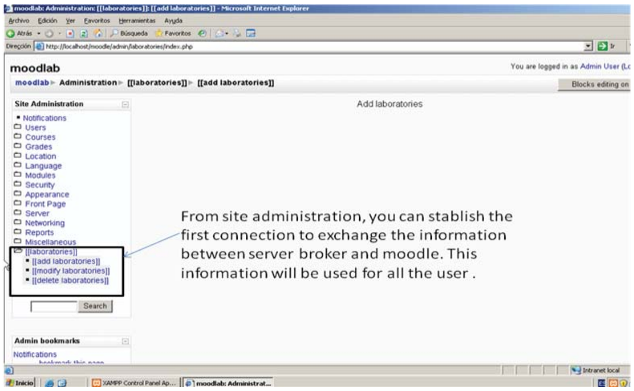

Figure 20. .Adding option to Administration site of Moodle.

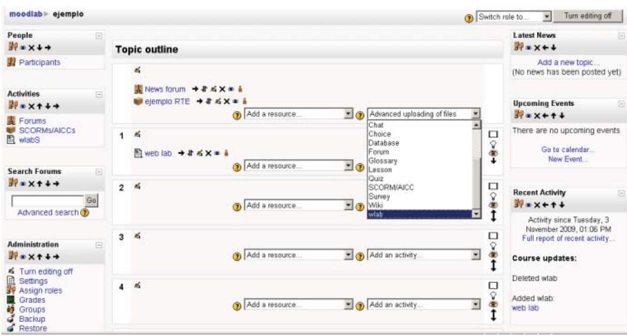

Figure 21. .Adding a web lab in a Moodle course.

VIII. Future works

This is a strong first step to connect LMS with iLabs and remote labs, and obtain shared labs, reuse of services and merge of these two solutions. But, of course we have to work in several important aspects:

- Design and implement web services in the open source LMS as Moodle or .LRN. For example scheduling service.
- Allowing LMSs and iLabs and web labs to use a single sign on
- Designing and implementing a enterprise service bus and the connector that systems need.
- Establish a common way to connect LMSs and iLabs and remote labs.
- Also we would like to work in the idea to describe web labs, so we can define an standard like WSDL or UDDI to search for web labs and bind with provider.

IX. Conclusions

We are working in a middleware and architecture that allow connect different systems and at the same time offer:

- Data transformation
- (intelligent) routing
- Dealing with security
- Dealing with reliability
- Service management
- Monitoring and logging

X. 8 Acknowledgement

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VirtuaLab, a Teaching/Learning System for 8 and 32 bits Microcontrollers

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Abstract— **This paper describes the current state of the VirtuaLab facility at the Universidad Carlos III de Madrid. Under an authenticated access, the system allows to control a microcontroller based modular system, with visual feedback to the remote user through a web camera. VirtuaLab allows control through Internet of the same laboratory resources used on–site sessions from inside and from outside the campus area.**

Keywords-virtualab; e-learning; microcontroller; ARM7; 8051

I. INTRODUCTION

Microprocessor learning sometimes becomes a hard assimilation effort to students, requiring in addition a lot of attention to details in order to accomplish the mandatory practical laboratory sessions, [1].

Furthermore the necessarily limited time assigned to each session can be not enough, by the own difficulty of the exercise or because the student has the will to get a better insight of the full system working.

Although the market offers low cost evaluation microcontroller boards, buying one kit is not a common approach for a typical student, so the possibility to access a remote laboratory adds a useful complement to the traditional sessions into a laboratory with fixed training schedule.

This paper presents a modular system which can be used both into on–site sessions, and also from Internet using a software application which gets the total control of the PC based development platform, located into the real laboratory.

The developed platform is flexible enough to integrate available commercial evaluation boards, so avoiding microcontroller obsolescence and easing the migration to new models with low effort, [2, 3]. In this way, we use a project based learning approach, in the same path that other authors have followed before, [4, 5, 6].

Organization of the paper is as follows: section II explains the HW resources of the platform, while section III details the SW solution adopted in order to manage the access to system and to administrate the users Data Base; section IV describes some of the laboratory assignments to students. Finally, section V presents the evaluation results, and section VI summarizes the main conclusions reached during the life of the project.

II. HARDWARE DEVELOPMENT PLATFORM

A. Microcontroller board of 8 or 32 bits

The system can use any microcontroller of 8, 16 or 32 bit, usually included onto a commercial evaluation board, which makes the full system close to a real application. The actual system built use two completely different chips:

An 8-bit system, actually the evaluation kit C8051F226DK from Silicon Laboratories, a model derived from the original Intel 8x51 design.

A 32-bit system, the Keil MCB2100 kit that includes an evaluation board for the NXP-Philips LPC2148, based on an ARM7 CPU, a more complex and powerful model [2].

We have designed the board E/S MICROS in order to have control of different peripherals. The different interfaces use a specific I/O pins assignment and routing board for each one of the microcontrollers and, of course, requires its own software routines.

This special pin adapter board allows the connection of the concrete evaluation board used with the E/S MICROS one, using flat cable. The last one includes several input/output peripherals, which the user can freely combine.

Usually students program its assignment works on C and Assembler languages.

Actually, we are using IDE from Silicon Labs and µVision3 from Keil/ARM as development environments, which include tools that let to edit, assemble, compile and link programs, and then run and debug it when they are errors' free.

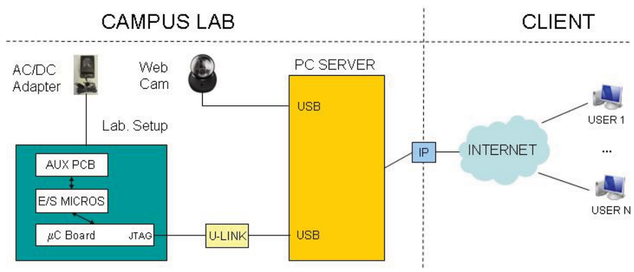
B. E/S MICROS peripheral board

This board includes a keyboard/keypad, an LCD liquid crystal display, a LED's matrix, an RS-232 serial port, an I^2C EEPROM and I^2C potentiometer, an infrared receiver, and a triac for AC phase control.

An expansion board adds to this E/S MICROS some peripherals, better placed outside of it because of space constraints: these are a little speaker, a power relay, a DC motor and a photo detector of the motor axis spin.

Keyboard: is has a 4x4 cross-matrix organization.

Figure 1. Schematic diagram of the complete system



LCD liquid crystal display: the character display module has two lines of 16 symbols. The HW interface is common to several models, making feasible to mount another one with a different number of lines or character, e.g. 4x20.

LED's matrix: this display has a 7x5 dots format to show the desired configuration. To reduce the number of pins, the microcontroller connect through the serial input of two 74HC595 shift registers, and its parallel outputs connected to ULN2003A drivers.

RS-232 serial port: this module includes a MAX233 level converter and a standard DE-9 connector.

I^2C devices: the board includes two devices with this type of interface: an EEPROM memory and a digital potentiometer. The 24LC16 memory has 16 Kbits but a higher capacity model can replace it. The DS1803 digital potentiometer, with 256 different output levels, controls the DC motor through an amplifier, and can connect to other devices.

IR receiver: With this device, it is possible to implement an infrared remote control that offers complete user isolation from AC powered devices, and allows controlling onboard peripherals through a remote wireless channel. It uses the Sharp IS1U60, an infrared receiver with a lens included.

AC phase controller: With this module, it is possible to manage up to 1 KW, through the triac phase control of an AC line. To get a safe operation, opto–isolators completely separate the power and control sections.

Speaker: a microcontroller output reaches an audio amplifier and this to a little speaker. A manual amplifier gain control, allows adjusting the volume of sound. By creating a memory table of frequencies associated to each musical note, it is possible to associate a different tone to each key or even play previously stored melodies.

Figure 2. View of E/S MICROS peripheral board

Figure 3. Platforms for ARM7 and 8051 VirtuaLab

Relay: it can switch on or off, signals of relatively high power, with galvanic isolation from control electronic.

DC motor: this type of motor finds typical application on micro-robots, toys etc. Its can be controlled directly with a variable DC voltage or through a PWM signal, which is the preferred technique. The module includes also a motor spin detector, based on the H21A phototransistor optical switch; to this end the motor mounts an X shaped piece fixed to the axis, which cuts the light path when spinning.

C. *Complete hardware platform*

Fig. 3 shows the two platforms, including the following components: microcontroller evaluation board, E/S MICROS board, expansion board, interconnecting cables and two supporting plastic sheets, the upper one of transparent polycarbonate.

Also included is a webcam of 640x480 pixels resolution and maximum rate of 30 fps and an auxiliary lamp. The visualization software is the AMCAP v1.00 bundled with the Trust Spyc@M100 camera model. In this application, we do not have special video bandwidth requirements, [7].

This constructive system based on independent modules, makes possible to protect effectively the HW of improper user handling. At the same time, it makes easy the substitution of modules by obsolescence, fault or upgrade, [8].

III. SUPPORTING SOFTWARE

The management and control software of VirtuaLab has been developed under Delphi. It uses the Windows Remote Desktop to access from Internet an on–site laboratory where a PC computer runs Silicon Labs IDE or Keil µVision3. The system authenticates the user to verify its access rights, and then he can work up to a maximum allowed time of 1 hour.

To get access, the PC requires a name and password fig. 4. When the system is busy, it denies the access, as VirtuaLab attends one user at time while working in non-stop mode.

A user is blocked after some failed access attempts but after a 24 hours lapse he is automatically restored. Five minutes before the session ends, the system sends a warning message to close opened files and save code changes, fig. 5.

Figure 4. Access screen to VirtuaLab

On the PC client side, the user needs a remote desktop connection, but a high-speed link is not required. Universidad Carlos III offers to its students several rooms with access to a large number of computers connected to Internet. By using these PC or a wireless notebook connected to the local Wi–Fi, it is possible to access VirtuaLab from inside the academic campus. The students also can access the system from outside, for example from the own home through Internet.

After login, the user execute the webcam and IDE programs from the start menu of the remote laboratory PC, and begins to work as if he were into the lab, near to the development platform.

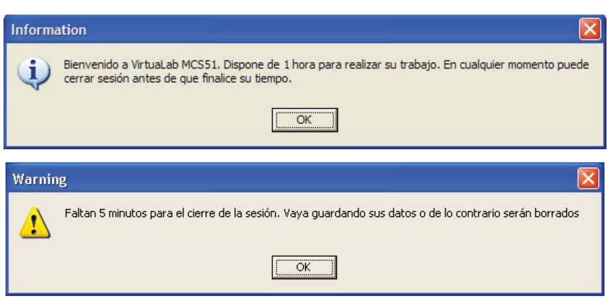
An obvious limitation of the system is that the input keypad is not physically accessible. In this case and when debugging an application, the user must use some technique equivalent to the keying action, e.g. changing a register or variable using a program breakpoint.

As a help to the instructor, it is possible to run an auto-test program, which allow verifying the integrity of any of the HW modules included in the system. This tool is useful to confirm that there is no hardware malfunction so a program module is incorrect and also to locate and repair a device fault.

The availability of a library of functions, which handle the full set of HW resources, offers the possibility of making some complex practices before the students have developed and debugged their own programs for all of the required modules.

Two library sets are available, one for each microcontroller model, in order to use, invoke and link without access to the source code. This feature has probed to be a strong advantage to learn the functionality of the full system.

Figure 5. VirtuaLab Welcome and Timeout warning screens



The Data Base includes a record of students, which can work with VirtuaLab, a timetable of its assigned slot time, and a historic register of accesses to system. If a student does not login the system within 15 minutes after the beginning of its time slot, any other user can gain access to it. This rule allows that anyone can use the system when it is idle.

Several security layers are included to avoid undue access to system. For example, to key the password the student uses a mouse over a virtual keypad onto the screen. As additional protection, we use an encrypted hard disk database, to avoid changes made by non-authorized persons.

The system administrator has its own special password to access database records, listings and control screens. In this mode, it is possible to get individual, group or global reports, selecting different fields of interest. Administrator can insert/delete users, manage blocked accounts, see access and time history, make searches by name or group, and define reports listing. Recording the number of access and consumed system time helps the evaluation of each student and group. The graphic interface has been refined along several years of use, in order to be intuitive and user friendly.

IV. Laboratory Projects

Let us shortly describe, some of the practical exercises proposed to students of different engineering degrees:

A. *Using 8051*

1. Speed control of a DC motor: the speed must change under keyboard command. The measured speed on rpm shows over the LCD. The program should use specific functions to develop. The user writes and debug in assembler and in a posterior session, he do it again using only C language.

2. LCD scrolling display: includes the use of keypad and LED's matrix; shows a 4-line message on a 2x16 LCD.

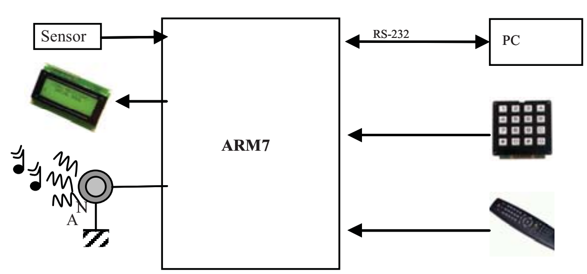
3. Serial link: communicates the microcontroller through a RS-232 interface with HyperTerminal running on the PC. LCD upper line shows data received from PC and the lower line show the data entered through keypad and sent to PC.

B. *Using ARM7*

4. The assignment is to build a complete alarm system, following a progressive process along several sessions, [9].

The alarm system detects presence with an analog sensor input, whose value must be higher than a certain level. In this case, the system generates an audio alarm and sends a message to a PC through the serial port.

Figure 6. Domestic alarm system based on VirtuaLab



The alarm system starts by entering its PIN number and silence by a command sent through the IR remote control. The system signals its state on the LCD, adding audible feedback to entered keys. It is possible also to activate the audio alarm from the PC sending a special message.

The last sessions are usually very instructive for the students, when the working team of each group must resolve some rather unexpected integration problems.

V. EXPERIENCE RESULTS

The Electronic Technology Department of Universidad Carlos III de Madrid UC3M, has 50 full kits for laboratory practices, including the I/O boards and the corresponding evaluation boards for microcontrollers of ARM7 and 8x51 families: Keil LPC2129/MCB2100 and Silicon Labs C8051F226.

Courses belonging to different three years engineering degrees at UC3M use this equipment kits at on–site labs. Actually, these second year courses belong to three different degrees:

- SED II, 8051 based. Degree ITI Electrónica Industrial (EI)
- SED, ARM7 based. Degree ITT Sistemas de Telecomunicación (ST)
- Microprocesadores, ARM7 based. Degree ITT Telemática (Tel)

A. Academic results

The following histograms summarize the results of several years and degrees. The X-axis shows reached marks from zero to ten, and Y-axis the annual percentage of students within a mark in that course.

For SED II we have 4 years data, from 2006 to 2009.

The data on SED covers from 2007 to 2009, and we only show the histogram for the three years average.

On Microprocesadores, we have data from 2006 to 2009 while fig. 7 shows the average histogram for these 4 years.

Figure 7. Four years academic results from SED II (EI)

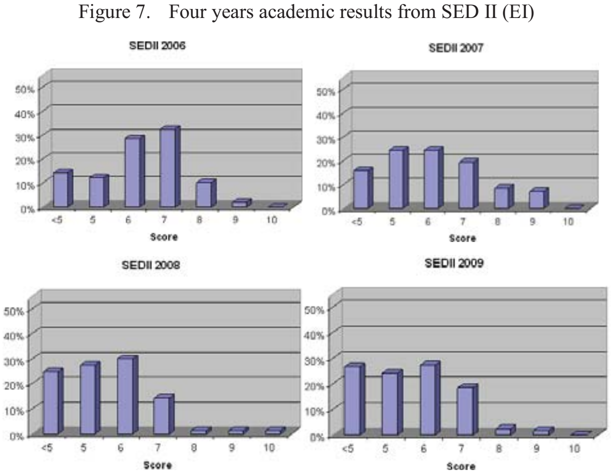
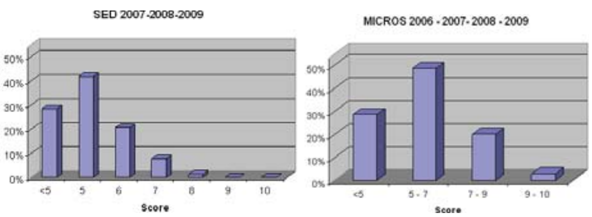


Figure 8. Academic results of SED (ST) and Microprocesadores (Tel)



B. Student perception of results

We have carried some surveys on students the first two years after the introduction of the remote lab. Tables show the results for SED II on 2007, which agrees with other courses.

- General questions:

Q1: My topic interest has increased after the practices

Q2: I should like to study an advanced course on this topic

Q3: Practices are useful to understand the theory

Q4: Tell if the practices balance is right

- On–site Laboratory

Q1: Mark the usefulness of this type of practices

Q2: It promotes to work into a group

Q3: The number of exercises has been enough

- Remote Laboratory VirtuaLab

Q1: Mark the usefulness of this type of practices

Q2: It promotes an individual work

Q3: Working remotely with VirtuaLab has been easy

TABLE I. STUDENTS PERCEPTION AT SED II (EI)

General questions	Responses					
	1	*2*	*3*	*4*	*5*	*Av.*
Q1	1	3	2	10	9	3,9
Q2	2	2	9	9	8	3,6
Q3	0	1	3	15	11	4,2
Q4	3	2	4	11	10	3,8
On–site lab	**Responses**					
Q1	1	3	4	15	7	3,8
Q2	0	0	5	11	14	4,3
Q3	2	3	3	6	16	4,0
VirtuaLab	**Responses**					
	1	*2*	*3*	*4*	*5*	*Av.*
Q1	1	3	2	10	9	3,9
Q2	2	2	9	9	8	3,6
Q3	0	1	3	15	11	4,2

Marks qualifies from 1 (strongly disagree), to 5 (strongly agree)

In general, we think there is not a clear difference on the average academic results due to the introduction of the remote lab, although this is true for the more interested individuals, [10]. The student perception of VirtuaLab is good, but cannot be used to a fair comparison, because they have no experience of the same practices with and without a remote lab.

VI. Conclusions

The major perceived effect of access to VirtuaLab laboratory is an increase of the time students spend working with the microcontroller platform, because of some well-known real practical constraints, that up to now only this approach has probed to solve.

The remote lab is a complement to the conventional one, as it cannot completely replace it, although it is still possible to apply the transfer of training concept, [11].

Other studies as [1, 12, 13], have not detected any significant difference of results between remote and on–site labs of similar contents, in agreement with VirtuaLab findings.

Therefore, this additional time devoted to put in practice the concepts explained at classroom, is likely to increase the practical development skills of students, and as a consequence a better insight of the course topic.

From the point of view of instructors and school management, there are also significant gains in terms of time and resources assigned to classroom training, as more students can progress by auto learning, without close teacher attention.

VirtuaLab offers conceptual advantages from different points of view: a flexible HW platform able to use any microcontroller based on commercial evaluation boards, changing only a passive I/O pin routing adapter, and a mechanical design able to withstand heavy use, protecting effectively the platform of improper user handling. At the same time, it is easy to substitute any module by a fault or upgrade to a new microcontroller, [8].

From the SW side, it allows students a local and remote access to develop, download code into microcontroller flash memory, debug and run a program, while records its working data for teacher's control and management.

As a dedicated system, VirtuaLab allows the control of a broad range of peripherals, has flexibility to change easily the microcontroller board avoiding obsolescence, and to control the students working time, all of these maintaining the same HW platform used in an on–site lab.

However, as the market evolution brings cheaper boards and link dongles, the use of low cost individual trainers could become a real alternative to these dedicated types of systems.

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Implementation of a Remote Analog and Digital Communications Lab for e-Learning

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***Abstract*-- A remote instrumentation model used to perform modern RF and digital communications experiments over the internet is presented. The setup allows for highly cost effective and pedagogically rigorous mechanism of instructions for students in situations where traditional laboratory equipment is either unavailable or at a premium cost. In the model, a switch matrix is used to eliminate the need for students to be present in the laboratory.**

Index—Remote, Analog, Digital, E-learning

I. Introduction

Rapid changes in the field of engineering technology have increased the need for universities to provide engineering and engineering technology students with meaningful and relevant practical experiences. However, limited available resources in the provision of laboratory hardware and infrastructure have been the principal impediment in achieving this objective. Such hardware limitations have been increasingly marginalizing the quality of engineering and engineering technology education. E-learning can be used to help universities and technical collages overcome this problem and one approach is to expand e-learning activities in programs with limited resources to take advantage of online computer-based technology. In this model, remote instrumentation technology and the internet are merged to interface students with the physical world. As such, remote laboratories allow students around the world to access a computer equipped with the suitable interface circuits, such as data acquisition systems connected to various sensors or communication modules, and perform real-time experiments. Each year, a growing body of work has appeared that has further validated both the technological viability of distance laboratories, and their effectiveness in delivering a worthwhile laboratory experience [1-4]. The quality of the architectures and designs has shown steady improvement, and there appears to be ample evidence that this form of experimentation delivers a valuable learning experience for students [5-9].

In this paper, a setup is proposed to perform modern RF and digital communications experiments remotely in a distance learning environment. The National Instrument Educational Remote Instrumentation Suite (NI ELVIS) and Emona Instrument's DATEx telecommunications trainer [10-11] were utilized in this setup. An amplitude-shift keying (ASK) experiment was performed online to demonstrate how students can easily carry out many tedeous tasks to perform the experiment; and hence focus on understanding the underlying principles of operation of the communication systems.

II. Remote Laboratories

Hands-on laboratories provide valuable experience in engineering and technology education. However, such trainers are not always necessarily available to students. Limitations on equipment access and funding further reduce the availability of laboratory resources in many institutions. Virtual laboratories are therefore a possible alternative to traditional laboratories, and they are already used in distance learning education in several universities. On the other hand, remote labs help alleviate these problem by increasing access and simultaneously reducing cost and a growing body of work has appeared that has validated both their technological viability and effectiveness in delivering a worthwhile laboratory experience. Over the past 10 years, two primary solutions have been implemented. Recently reported work continues to mirror this trend [12-17]. Some researchers have developed customized hardware and software that enables management and control of the process including data-based driven web pages with access scheduling. Others have chosen to employ commercial platforms, e.g. LabVIEW in combination with NI ELVIS. We decided on this latter approach since ongoing support, maintenance and design improvements would be readily available from the supplier network.

The NI ELVIS II can be used in many electrical engineering laboratories. In addition to its built-in instruments, it can be used to build LabVIEW-based remote instruments, a multifunction data acquisition device and a custom designed bench top workstation and prototyping board. The Main features on ELVIS II, shown in Fig. (1), are:

- Offering modern digital and analog experiments in a single board.

- Hands-on experiential system featuring a widely accepted block diagram modeling approach.
- Featuring a USB plug-and-play interface for flexible setup.
- Operation in both local manual mode and under fully integrated Lab VIEW software control.
- Out-of-the-box curriculum for telecommunications concepts.
- LabVIEW Programming and LabVIEW Signal Express software.

The Emona DATEx electronics training circuit board (ETCB) is a plug-in trainer board module that works in concert with and a personal computer to provide a solution for students who need to perform laboratory experiments, whether at a distance or on campus. It plugs into the NI ELVIS II as shown in Fig. (1). All essential hardware devices/blocks in the laboratory are housed in this single board which possesses the capabilities needed for implementing dozens of telecommunications experiment. It actually includes more than 20 circuit blocks for basic telecommunications operation such as adder, multiplier, mixer, signal generator and phase shifters, which can be effectively used in the construction of block diagrams by patching them together according to theoretical block diagrams. User management of this telecommunication bundle occurs in a PC-based control mode using LabVIEW and DATEx SFPs software to give the students the freedom to build communications systems hardware by joining together circuit blocks similar to those studied during the class.

Fig. (1): Emona DATEX Set-up for Use in Communications Labs.

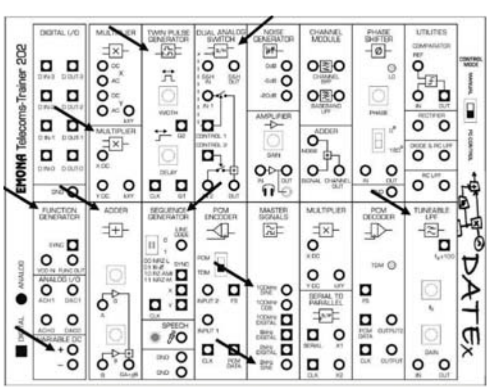

Fig. (2): Emona DATEx Front Panel.

The proposed architecture for this remote telecommunication lab is shown in Fig. (2). The main part in the lab is the ELVIS II-DATEx set-up. Experiments can then be setup up and conducted using this flexible platform where all programmable devices are controlled by digital signals, originating from the experiment server, through a multifunction data acquisition (DAQ) card. The user interface for a given application can also be created quickly and simply by LabVIEW, as this graphical development environment does not require any line of traditional text-based code to create such applications. LabVIEW subroutines, called virtual instruments (VIs), are composed and programmed to control the experiments. These VIs are hosted on the VI server as shown in Fig. (3). The programmer can use readymade VIs or compile and customize new ones that achieve the desired requirements. The remote experiment can be run from anywhere inside a local area network (LAN) or globally via the internet. The application is usually published with a web publishing tool, which converts the VI front panel into HTML format that can then be hosted by the web server. The client students can actually access the experiments with simple internet web browser in the same way a conventional website is accessed.

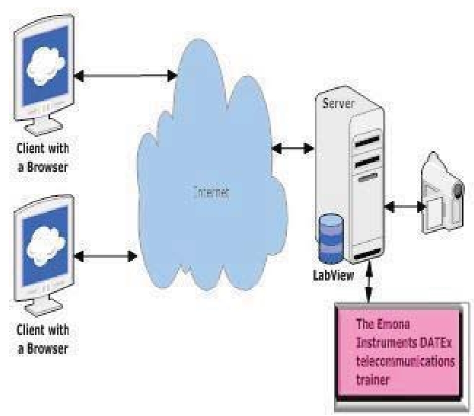

Fig. (3): Remote Communications Laboratory Based on the DATEx-ELVIS II Set-up.

In order to perform RF and digital communications experiments there is a need for eliminating the user interface needed to perform the required connections for modules. This setup has been prepared for students with only basic knowledge of mathematics and limited background in physics and electricity. The user interface can be controlled through a switch matrix that makes the lab setup accessible to the on-line community and obviates the necessity for physical presence of students in the lab to implement the necessary connection for the experiment being performed. Students can log in and generate their own AM/FM/BPSK signals, set up a bandwidth limited signal and explore its spectral composition. In addition to providing online laboratories, this remote laboratory may be a suitable way for on-line instrument evaluation.

III. SAMPLE ANALOG LAB: ADDING 2 SIGNALS

The Emona DATEx can model communications equations to bring them to life. This sample experiment will introduce you to modeling equations by using the Emona DATEx to implement two relatively simple equations. The steps needed to perform such an experiment using the standard ELVIS II-DATEx setup are as follows:

1. Launch the DATEx soft Front-panel and the NI ELVIS Oscilloscope Remote Instrument.
2. Locate the Adder module on the soft Front-panel and drag its G and g controls to about the middle of its travel.
3. The setup is implemented in the Front panel window by turning on the respective nodes.
4. The scopes time base control is tuned to view two or so cycles2khz sine output and measure the amplitude.
5. Now just disable the adder module's B input and activate the scope's channel B input by pressing the channel B controls on/off.
6. Adjust the Soft G control by using the tab key and arrow keys for fine adjustment.
7. Enable the B input then disable the A input and adjust the g control till the output voltage is same as the input voltage.
8. Enable the A input and you can implement:
9. Adder Module Output = Signal A + Signal B

This standard procedure may be followed by student in the lab in order to perform the experiment. This presence, however, can be eliminated when a computer-controlled RF switch matrix is used. These switch matrices are currently available from several manufacturers including National Instruments.

IV. SAMPLE DIGITAL LAB: AMPLITUDE SHIFT KEYING

Amplitude-shift keying (ASK) is a form of modulation that represents digital data as variations in the amplitude of a carrier wave. The amplitude of an analog carrier signal varies in accordance with the bit stream of the intelligence signal (modulating signal) keeping frequency and phase constant. The level of amplitude can be used to represent binary logic 0s and 1s. A carrier signal may be treated as an ON or OFF switch. In the modulated signal, logic 0 is represented by the absence of a carrier, thus giving OFF/ON keying operation. Fig. (4) shows the implementation of ASK modulation using the Emona 202 telecom trainer.

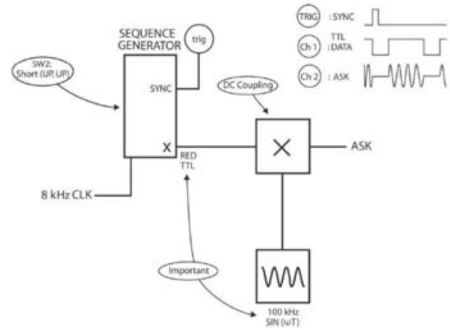

Fig. (4): Amplitude Shift Keying Set-up.

ASK modulation can be performed in a very easy way. The modules Sequence generator, Masters signals, Dual analog switch and oscilloscope are used for connections. The connections will be as follows:

1. Oscilloscope Ch 0->sequence generator X->Dual switch control2.
2. Oscilloscope Ch1->Dual switch out,trigger-> sequence generator sync,
3. Masters signals 2 KHz digital and 2 KHz sine -> sequence generator clk and dual switch IN2.
4. ASK signal's carrier and the sequence generator module's clock are the same frequency.

This experiment has been designed to make the ASK signal easy to monitor on the scope. Ideally, the frequency of the carrier signal should be much higher than the bit-rate of the digital signal supplied by the sequence generator module's clock frequency. The seuence generator module is used to model a digital signal and its sync. output is used to trigger the scope to provide a stable output, and the dual analog switch is used to generate the ASK signal.

Students do not have to perform many tedeous connnection tasks to perform the experiment; rather, they can focus on understanding the communication system and its components.

V. STUDENTS FEEDBACK ABOUT THE USE OF THE DATEX TRAINER / ELVIS II SET-UP

A survey was conducted to get students feedback about the use of the ELVIS II-DATEx communication trainer set-up in the lab. 20 students who used the set-up in their RF communications lab in the spring 2009 semester, and who are currently taking a data communication class and using the same set-up for the second semester.

The following questions about students experience in using the Emona-ELVIS set up in ECT352: Analog Communications (COMI) and ECT 361: Digital Communications (COMII) laboratories were used for the survey:

1- Do you feel comfortable using the Emona-ELVIS setup?

2- Where the Emona-ELVIS setup experiments clearly written?
3- Where the Emona-ELVIS setup experiments procedures easy to follow?
4- Does the use of the Emona-ELVIS setup increase your interest in the labs?
5- Did you have difficulties in configuring the Emona-ELVIS setup software?
6- Did you have difficulties in configuring the Emona-ELVIS setup hardware?
7- Was the Emona-ELVIS setup very valuable in terms of teaching and learning?
8- Overall, do you support the use of the Emona-ELVIS setup in the Communications labs?
9- Would you like to see test set-ups similar to the Emona-ELVIS setup integrated into other labs?

The survey was conducted for 16 students enrolled in two different lab sections, and the results of the survey are illustrated in Fig. (5). In this figure, the blue (light) bar represents a "YES" answer and the red (dark) bar represent a "NO" answer. The X-axis represents the question number, and the Y-axis represents the frequency of each answer.

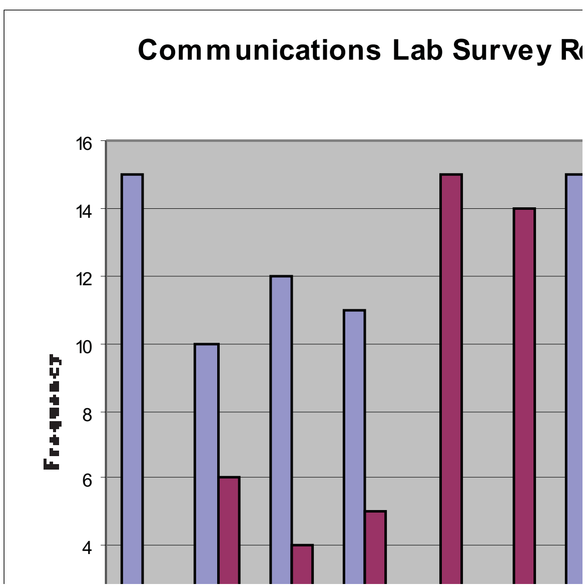

Fig. (5): Communications Lab Survey Results

From the results we see that there is a total agreement among students that they feel comfortable using the presented set-up. Only few students were not comfortable with the clarity of the experimental procedure for the labs. Students were comfortable using the LabVIEW software and the Emona-ELVIS II hardware set-up, and they overwhelmingly support the use of similar set-ups in other technical laboratories.

Conclusions

A laboratory design concept to perform RF and digital telecommunications experiments remotely in a distance learning environment is proposed based on an ELVIS II/DATEx trainer. In this model, a switch matrix is used to eliminate the need for students to be present in the lab. This setup allows for a highly cost effective and pedagogically rigorous mechanism of instructions for students in situations where traditional laboratory equipment is either unavailable or at a premium cost.

Assessments of the system show a strong interest of students on remote experimentation especially for those who cannot physically attend lab sessions to obtain hands-on experience. In addition, most of the class opined that it helped them to better understand syllabus topics and gain more applied knowledge. And the majority of students would certainly like to use remote labs in the future.

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Session 08B Area 4: Active Learning - Methodologies and analytic studies

Bringing the everyday life into engineering education

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Use of E-Learning functionalities: results of a survey along Spain

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Public University of Navarra (Spain); Spanish University for Distance Education-UNED (Spain); Technical University of Madrid-UPM (Spain); University of Jaen (Spain); University of Leon (Spain); University of Vigo (Spain); University of Zaragoza (Spain)

Active Learning in Power Electronics

Bellido, F.J.; Flores-Arias, José-María; Linán, M.; Moreno-Muñoz, A.

University of Cordoba (Spain)

Learning engineering by teaching engineering in the European Higher Education Area

Pueo, Basilio; Romá, Miguel

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Bringing the everyday life into engineering education

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Abstract— **To successfully design and engineer solutions for today's and tomorrow's rapidly changing and expanding global contexts, in which people are confronted with new opportunities and challenges each day, engineering programs should be training their students to become broad based professionals, who are aware of the actual needs, values and behaviors of the people that use their solutions in their everyday life, work or play. This paper argues that in order to built such an awareness, engineering students should acquire direct, first-hand experiences of real people in real contexts. It presents a number of techniques that can be used to gain such experiences. Each technique is briefly described and illustrated with examples from our Industrial Design Engineering program. Knowledge, skills and attitude that are acquired through the use of the techniques are listed and reflected upon. Finally, our experiences with implementing the techniques into our program are discussed in view of their relevance for other engineering programs.**

Keywords-industrial design; user centered design; generative techniques

I. Introduction

Traditionally, engineering schools have been concentrated on instructing students in a certain technical discipline, teaching primarily knowledge, skills and attitude specifically relevant for that field. Technical, domain-specific knowledge has been mainly transferred in classroom settings, directly from professor to student, while skills used to manipulate this knowledge have been trained in laboratory exercises and case studies. Both knowledge and skills was then to be directed by the engineering student towards the fulfillment of certain goals, which were influenced by personal values, concerns and preferences, together making up his professional attitude. Several authors, however, have claimed that such traditional instructional methods will not be adequate enough to prepare students sufficiently for today's rapidly changing and expanding global context, in which people are confronted with more and more social and technological opportunities and challenges, for which appropriate solutions will have to be designed and engineered.

Developments such as the explosion of information resources, the social responsibility of new technologies, the blurring boundaries between disciplines and the ever increasing need for sustainable solutions, all would call for the education of 'The New Engineer' [1,2,3, 5] or "Renaissance Engineers' [4]. Such an engineer should be a broad based professional who is socially and environmentally responsible [1], who understands the context in which he or she will work [2] and can marry technical abilities with a broader understanding of the world [4]. Furthermore, he or she should understand concepts that go beyond their own discipline as well as be capable of communicating their ideas to other disciplines, in order to work in multidisciplinary teams [3]. Finally, they should be people-oriented [5]. This means that students should able to develop an understanding of how end users will interact with their designs and prototypes, and what their reasons and motivations are for doing so. In this way students become more aware of the needs, values and behaviors of the people that actually use their solutions.

In this paper we focus on the latter, arguing that this awareness should be an essential component of the engineer of today and tomorrow and that it therefore should already be initiated during the engineer's training. Since most engineers work in industry they tend not to interact one-on-one with the people who directly should benefit from their services or solutions. End users are often seen as abstract concepts rather than real people, if they play a role at all in the process. An engineering solution is traditionally considered to be successful if it is effective, efficient or innovative, not if it is usable, desirable or pleasurable. However, in today's complexity, where people are overwhelmed with technology that is more powerful and complex everyday, these latter aspects are becoming increasingly important. Future engineers can not limit themselves to focus on purely technical solutions anymore, they have to broaden their perspective to understand how these solutions will affect the everyday life of the people that they intent to serve.

In this paper we describe our experiences of bringing this everyday life of people into a design engineering curriculum. Adapting tools and techniques from ethnographic research, we have been training our students to tap into the deeper needs, values and dreams of potential users, going beyond the traditional focus on product functionalities and characteristics. We explain how these tools and techniques are implemented in our curriculum, show some of their results in courses and projects, and discuss their implications for engineering education in general.

II. Background

TU Delft's Industrial Design Engineering (IDE) program has been in existence for 40 years. With more than 4000 graduates and more than 300 freshmen every year, IDE has established itself as one of the leading design programs in the world. Its motto is “creating successful product that people love to use”, concentrating on designing and improving products which are used daily and intensively, at home or at work.

The Bachelor's program in Industrial Design Engineering lasts three years, in which design projects provide a thread of continuity throughout the program as a whole. These projects provide the opportunity to apply the knowledge and skills that have acquired from the various disciplines related to IDE, being engineering, ergonomics, design, marketing and consumer behavior, and sustainability.

After successfully completing the Bachelor's program, students can move on to one of the three two-year Master’s programs in IDE:

- Integrated Product Design, intended for those seeking professional mastery at the highest level in the field of product design. The program centers around mass produced consumer products and includes product service systems and products for professional applications.
- Strategic Product Design , which teaches students how to choose a strategic product direction based on insights from the external environment (market analysis, consumer and behavior research, trends and future scenarios, governmental policies, and new technologies and materials) and the wishes and possibilities of the company (product strategy, brand identity, mission/vision, resources).
- Design for Interaction, which teaches students how to design innovative and appropriate products and services by placing the key aspects of human-product interaction, which are use, understanding and experience, in the centre of the design process.

Over the years, new design approaches like “user-centered design” [6,7] and “user experience design” [8] have found their way into all programs. A key aspect of these approaches is that they put the user and not the product at the heart of the process. Initially this primarily meant that users were considered as ‘research subjects’ which were studied by expert researchers or designers, in order to generate product requirements or to validate design concepts. Typical techniques included *interviews, contextual inquiries* and *observations*.

More recently, however, approaches like “participatory design” [9], “co-design” or “co-creation” [10] have promoted a more active engagement of end users by having them participate in design-like activities that are traditionally considered to be the domain of professional designers or engineers. By giving ordinary people (i.e., people with no professional design or engineering background) tools and techniques, such as collages, diagrams or models, they are given the opportunity to articulate their experiences in ways that are more visual and expressive, and consequently, more accessible and understandable. It can be said that increasingly designers are taking on the role of researchers, while users are acting more and more like ‘designers’.

This development in both design research and education has been paralled by a growing need from industry for designers that have the skills to tap deeply into the context in which today’s and future products will be used, including the needs, values and motivations of the people that will use them. It is felt that because of the ever increasing complexity of this context a better understanding of it is needed to successfully design products or services that will have to ‘live and survive’ within this context.

Therefore, in several courses and on several occasions throughout the IDE program, students are stimulated to directly interact with end users by visiting the locations where people work, live or play, observing their behaviors, studying their moods and emotions, getting insights in their desires and wishes as well as generating ideas and concepts together etc. In the next paragraph we will discuss some of the techniques that we teach, illustrated with examples from various courses and projects.

III. TECHNIQUES

In general, all techniques have their base in ethnography, which is the branch of anthropology that deals with the scientific description of specific human cultures. A core principle of an ethnographic study is that data is collected through direct, first-hand experiences of daily life. In recent years this principle has been adopted in the development of several techniques that should support designers and engineers in acquiring such experiences. In this paper we will present and discuss three of those techniques: interviews /contextual inquiry, observations and generative sessions. The scheme in figure 1 [11] nicely shows how these three techniques are related to the type of knowledge they produce and the kind of insights that can be gained from them.

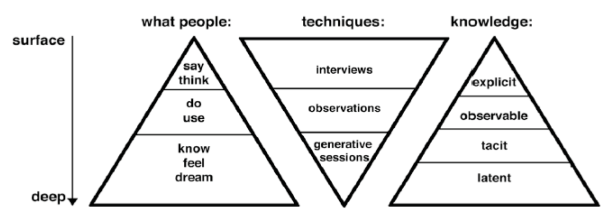

Figure 1. Relations between techniques, knowledge and insights [11] (used with permission.)

A. Interviews/Contextual Inquiry

Conducting interviews is a classical and often practiced technique to gather information from people. Typically an interview is a conversation between two or more people (the interviewer and the interviewee), where the interviewer asks questions to which the interviewee provides the answers. The style of the interview can vary from strict, where a predefined set of questions is closely followed, to more open, where the questions get adapted to the flow of the conversation. Interviews are particularly suited to acquire *explicit knowledge* on people’s current and past experiences. People are usually good at telling factual things, what they did or are doing now,

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where they did it, when, etc. However, while this can provide designers and engineers with useful information, it is usually not rich and detailed enough to provide directions for the actual design process.

Therefore, in order to acquire data that is more grounded into the contexts of people's actual life or work, a technique called Contextual Inquiry [12] is often used in design projects. This is also a structured field interviewing technique, however, based on four core principles that differentiate it from the plain, journalistic type of interview.

- Principle of context: Visiting and absorbing the whole context in which the tool, product or system to be designed will be used, is considered essential. Thus the interviews should always take place at the location where the new design will be used.
- Principle of partnership: Users are seen as partners in the design process, they are considered to be experts of their personal situations. Interviewing during a contextual inquiry therefore usually does not include set, broadly worded questions. Instead, the partnership between the interviewer and interviewee is used to create a dialogue, where the interviewer not only can determine the user's opinions and experiences, but also his intentions and motivations.
- Principle of focus: Throughout the inquiry, the interviewer should be constantly be aware of his focus, being a combination of his own assumptions, beliefs and concerns of the particular situation. All that is seen and heard is filtered through this focus and the return of the inquiry therefore heavily depends on 'keeping focused'. Expressing this focus to the interviewee also makes forming a partnership easier.
- Principle of interpretation: After gathering the data, meaning has to be assigned to it through interpretation. Since design and engineering is nowadays commonly done in (multidisciplinary) teams, the goal of the interpretation is to build a shared understanding within the team. This is usually done in an open discussion, where the interviewer walks through the results of the inquiry, while the other teams members listen, ask questions, make comments etc.

In the course Interaction and Electronics, which is running in the second year of the Bachelor program, students are given the assignment to design the user interface of a Personal Shopping Assistant (PSA). This is a small computer device with a touch screen, which is mounted to a shopping cart. All products in the store are marked with an RFID-tag by means of an adhesive label, storing a special number known as the Electronic Product Code. Through this unique code detailed information, such as manufacturer, shipping date, price, weight, and best-before date etc. can be retrieved of each product. The interface of the PSA should thus provide the customers of the store with to a number of functions which should support their shopping process. For example, the device might give suggestions on special offers and show where these products are located in the store.

To gather requirements for their design, the students have to conduct a contextual inquiry, studying real users doing real tasks in real situations. For this students visit stores, conduct short interviews with customers, observe their behavior, map out the layout of the store etc. They are urged to take pictures or shoot videos (if permission is granted) or otherwise capture the actual context as rich as possible. Taking into consideration that their subjects are not designers and are therefore not trained to think of new functionalities, they have to look actively for opportunities in their subjects' behaviors, needs, preferences, social activities, daily routines etc.

Consequently, the results of their contextual inquiries need to drive their further design process. This means that emphasis was put on producing rich and inspiring visuals of a highly informative character instead of thick and wordy reports filled with demographics and statistics. Experience has shown that such a format is much better suited to communicate to others, mainly because of it's compact and attractive qualities. Figure 2 shows an example of such a presentation format.

Figure 2. Infographic showing the results of a contextual inquiry

Another, popular way of condensing the results is by creating a *persona*, which is a fictitious character that is created to represent a user type within a targeted demographic that might use the product, system or service to be designed [13]. Personas give a human face to otherwise abstract data about potential users, thus helping to better infer what a real person might need. Creating a believable persona involves coming up with a rich identity and a visually compelling character that gives much relevant information for the actual design stage.

Figure 3. Persona depicting characteristics of a possible future user.

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Personas usually included a name, a photograph, a personal profile, interesting quotes, goals and motivators, etc. Again, by presenting the results of their study in such a way students are forced to stay close to the people they have interviewed, the situations that have encountered, the locations they have visited etc.

B. Observations

A technique that is often used in combination with or as integral part of a contextual inquiry, but can also be used independently, is observations. Carrying out accurate observations involves much more than just watching people doing things. It requires a sensitivity and alertness for the particular routines, behaviors and interactions people exhibit in certain situations. For this an open mind is as much needed as an open eye, since many of the things people do or how they behave in day-to-day situations, could easily be taken for granted. More than often there are conflicts in how people claim to behave and how they actually behave, without them being aware of it.

Good observation starts by deciding first what will be observed. Since many contexts are very rich, a clear focus is again essential not to get overwhelmed by all impressions. For this reason students are urged to come up with a plan before the actual observations are conducted. Being at the location, they are told to be as unobtrusive as possible in order to influence the context as less as possible. Camera's can be used to record interesting situations, but permission to use them should always be asked for. Things that can be looked for are certain routines as expressed through repeated activities, body postures or interactions. However, also extreme behavior should be recorded, since sometimes one 'strange' observation can trigger a whole range of possible solutions.

C. Generative sessions

While interviews, contextual inquiries and observations all can and will provide designers and engineers with valuable information about what people think, say, do or use, they tend to fall somewhat short when it comes to getting access to the deeper values, whishes and needs of people: what they know, feel and dream. In reaction to this, various method and techniques have therefore more recently emerged that try to address those latter type of information.

Within our IDE research program, substantial work has been done on the development of one of those technique, called *contextmapping* [14]. Building on the influential work of Sanders [15], contextmapping tries to create an overview of the context surrounding the use of a current or future product by gathering and analyzing personal experiences of real users regarding that particular context. Over last years the technique of contextmapping has been implemented in several IDE-courses [16].

The core of a typical contextmapping process is a so-called *generative session*, in which participants first create artifacts such as collages, diagrams or models, and then are asked to present and explain their creations. The premise is that through telling these often personal stories they are able to re-live previous experiences with a certain product, system or context more vividly and deeply. These stories are usually recorded on video and audio, and sometimes transcribed, for later analysis.

Preceding a generative session participants might receive a specially designed *sensitizing package* or *cultural probe* [17], which consists of small exercises or activities which are to be completed before the actual session. An often used format for such a probe is a workbook or diary, which contains smalls task for each day. The idea is that by doing these exercises the participants get triggered and motivated to explore the context of product use before the generative session.

After conducting a generative session the results are analyzed, usually by classifying quotes, observations, remarks etc. in meaningful categories. The conclusions are then to be communicated, again not in thick reports, but in ways that will enhance an understanding for and empathy with the users. Possible means for this are collages, card sets or diagrams. For an extensive description of the technique of contextmapping and generative sessions, the interested reader is referred to Sleeswijk Visser et.al.[11].

Exploring Interactions is a course in the Design for Interaction master's program. In this course students are required to formulate their own design project around a certain theme. The themes, for example Fear and Fearless, Power, or Trade, are quite broad and abstract, but so guide the students in their explorations and give them the opportunity to pick a topic they really like. The focus of the course is on analyzing and conceptualizing human-product interactions in relation to the physical, cultural, technological, and social contexts in which new product design(s) will be used. In other words, getting direct access to these contexts is a substantial part of this course.

Students are therefore encouraged to explore the context for which they intent to design. Observations and interviews are therefore extensively used, but considering the conceptual character of the course, many students also use contextmapping. Figure 4 shows an example of a workbook, used to sensitize possible participants of a generative session. The topic that is addressed here is shoes. The exercise on left asks people to describe or draw the shoes they are wearing on that particular day, while the exercise on the right is about visualizing one's appearance and the appearance of others.

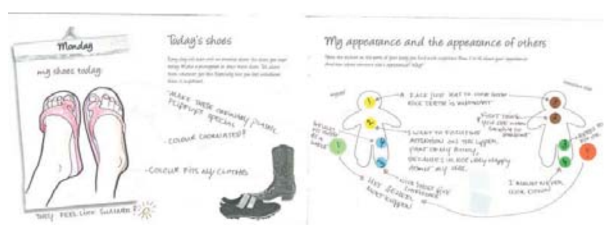

Figure 4. Example of a workbook, used to sensitize participants before a generative session.

The workbooks that are filled in by the participants, are subsequently used as input for the actual generative session, in which the topic, in this case living in a convalescent home or home for the elderly, is much deeper explored. Figure 5 shows a participant in an actual session, working on a collage that has to be presented and discussed later in the session. Sheets with inspirational images are given, but of course participants can also bring or create their own images, keywords etc.

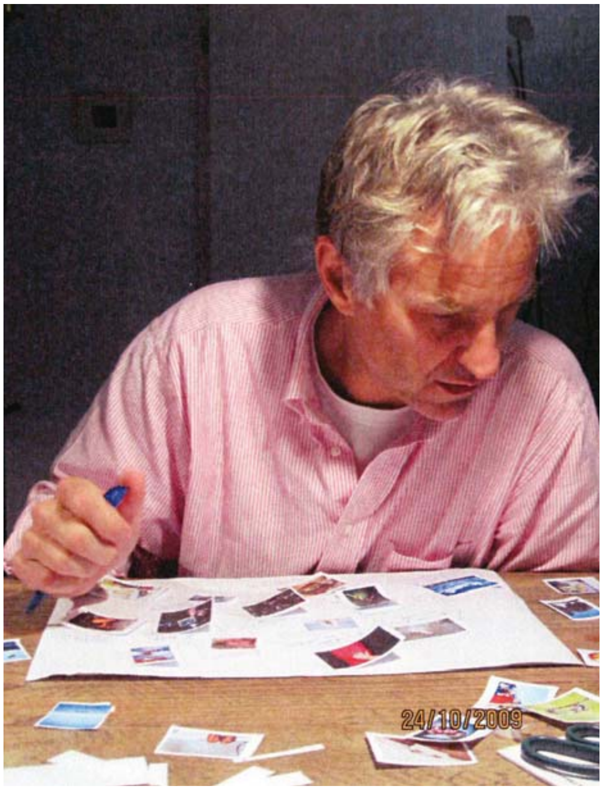

Figure 5. Participant creating a collage in a generative session.

IV. KNOWLEDGE, SKILLS AND ATTITUDE

Problem-based learning and realistic design projects are key in offering a rich and challenging learning environment; such realistic projects should be problem-based and should involve the activation of prior experience, the demonstration and application of skills, and the integration of these skills into real-world activities [18]. Throughout the IDE program, students work on several design projects, in which they apply their knowledge and skills, obtained in different courses, in an integrated manner to solve a real-life problem (similar to those they will encounter in their professional career). The integration of knowledge, skills and attitudes is at the origins of competency-based learning and is therefore increasingly being incorporated into university programs in general [19].

Central in all of the techniques described in the previous section is that they require students to leave the comfort zone of the classroom and take their presumptions, beliefs and ideas out into the real world. Through this they gain access to a different kind of knowledge, that is based on everyday life experiences instead of textbook examples. Furthermore, they get to train and sharpen their research and communication skills. Interestingly, we have noticed that the direct confrontation with real life situations and the interactions with ordinary people stimulates them to reflect on their personal attitude towards people, problems as well as their own role as designers and engineers.

A. Knowledge

Experiences from various courses and projects have shown that the techniques provide our students the means to tap into a rich and valuable body of *experiential knowledge*, which they could not have acquired in the classroom, from textbooks or from websites. While in education most situations get abstracted and simplified in order to demonstrate a certain principle or phenomenon, in real life such abstractions hardly exist. By studying the rich contexts of everyday life through direct interactions with the people who live, work or play in them, students are encouraged to put the mostly theoretical knowledge that they have acquired through their formal education into a different perspective.

This can lead to new discoveries and insights. More than once students reported how seemingly simple and ordinary situations turned out to be very rich and complex when researched carefully. They were often surprised to see what people actually do, how they use products in ways totally different from the instructions in the user manual, how they have developed certain routines to interact with other people, products or systems etc.

B. Skills

The specific nature of the techniques, with their emphasis on direct, first-hand experiences, on active collaboration and on visual, design-directed communication, also comes with a specific set of skills that is desired to successfully apply them.

First, the cooperative nature of the techniques requires students to practice their *communication skills* with people who have a different mindset, a different jargon and different set of needs and values. Contacting ordinary people, talking with them about their every experiences, listening to their wishes and concerns without prejudices, explaining goals and motives to them in non-technical terms, involving and stimulating them into design-like situations; these all require good 'soft' communication skills that are usually not engineers' greatest forte. With projects becoming more and more multi-disciplinary, such skills have an increasingly valuable quality.

In preparing the material, such as for the workbooks or the generative sessions, research questions or topics should be presented in an attractive way to stimulate participation. Furthermore, communicating the results of the techniques usually involves condensation and translation of the results in ways that should be easily understandable as well as highly informative. Therefore students are stimulated to create infographics, collages, moodboards or storyboards. We have learned that through their abstraction and attractiveness, these means communicate much better than thick, wordy reports. In addition, students' *presentation skills* are also heavily trained in conducting these techniques.

Finally, by interacting with people with different backgrounds, with different levels of education, coming from different cultures, students also train their *social skills*. By having to involve and motivate participants or having to facilitate and direct group sessions, students develop a better understanding of and feeling for how to deal with group dynamics, social or economic status and differences in personality. Again, such skills are very valuable for working in today's and tomorrow's complex, global society.

C. Attitude

All techniques that are discussed in this paper share the simple premise that first-hand experiences of the context to be designed or engineered for are essential when solving problems for this context. This requires from students that they step out of their comfort zones, not just on a physical level by leaving the classroom and going out on the streets, but even more so on a mental level, by leaving the comfortable, well-known environments and mindsets of design or engineering students and entering the everyday life of real people in real contexts.

From our experiences so far we can conclude that this change in perspective enabled our students to establish a much deeper and richer contact with their users, learning about ordinary situations, rituals and problems directly from the source. They have developed a greater *awareness* of basic human needs, values and limitations, which helps them to better assess the qualities of their own ideas and solutions. Furthermore, using the techniques and learning from their experiences most likely enhances their *sensitivity* for possible problems or opportunities in their own context.

Finally, from a learning perspective, the informal character that can be found in, for example, generative sessions, in which designer and user work side-by-side might even transform the learning process from a one-way knowledge transfer into an interactive, two-way dialogue in which both engineering student and potential user dynamically learn from each other.

V. Discussion

So far in this paper we have presented our view that students in engineering disciplines need to develop a better understanding of today's rich and complex contexts and the people who live in them, in order to design and engineer successful solutions, now and in the near future. We have argued that such an understanding can best be acquired through first-hand encounters and we have therefore presented our experiences with a number of techniques to tap into the everyday life of real people in real situations. We have explained each technique and illustrated it with examples. Finally, we have discussed how these techniques have contributed to the competences of our students.

It might be clear that we consider it essential for upcoming designers and engineers to acquire a thorough understanding of the user and the context of use. However, putting this into the curriculum does not automatically lead to applying these additional competences in practice. Learning by doing is crucial for obtaining a good understanding of these techniques. Moreover, not only a proper execution of the techniques need to be learnt, students also need to be able to select the right technique that fits the current research and design goal. This is not trivial. In their first practices students might start quite axiomatically 'we have to do the workbook now' and only after more design experience, their confidence and awareness on how the different techniques can be helpful in design projects increases.

Interestingly, the quality of data collected by teams that deliberately select a certain technique usually is much richer and better suitable for inspiring the design process, whereas teams that just execute some technique might get disappointed, as their data did not show something they did not know beforehand. In fact, starting with an attitude to get evidence for preconceived ideas often does not gain new insights as well. In sum, the techniques we presented here are meant for idea generation, they do not focus on validating results.

Furthermore, we would like to emphasize the value of qualitative data. High numbers do not automatically stress importance of a topic. Many remarks in the same direction might just be an indication of the obvious, while one peculiar quote could trigger a whole new design direction. Thus not only using the right techniques, but also the ability of analyzing and interpreting the data collection is important. Moreover, in order to use these insights to inform the remainder of the design process, the knowledge transfer of user insights and requirements should be carefully guided.

As said before, the learning by doing approach has been taken to emphasize the previously discussed knowledge, skills and attitudes in the curriculum. For this reason, a lot of studio work has been reserved in the curriculum. Although part of a learning-by-doing approach is self-study, it also requires an intense tutoring system to stimulate reflection and discussion, which is time-demanding for our teaching staff. Applying the techniques is also work-intensive for the students. Collecting data through observations and interviews, preparing sensitizing packages, conduction generative sessions, analyzing the data; communicating the results: these are activities that require considerable time, effort and dedication. The pay-off, however, is often a very rich set of possible design directions.

One might argue that our program is be much more design-oriented and human-centered than traditional engineering programs, such as mechanical or electrical engineering, and that therefore the presented techniques are much more suited for our students than for 'hard-core' engineering students. Design students would have to have a profound understanding of the everyday needs and wishes of prospective users, since consumer products that are unwanted, unusable or undesirable would simply be rejected by the market.

While this might be true, it is strongly believed that these techniques could be of value to more traditional engineering disciplines as well. After all, even very technical and professional products or systems have end users too. Real people with various backgrounds, that have to service, maintain, monitor or operate increasingly complex machines and devices in increasingly complex contexts and situations. Shouldn't these people have the right to work with products and systems that are usable, pleasurable or even desirable too? And isn't it the obligation of the engineer, most likely in collaboration with other disciplines, to provide them with products and systems that have those qualities?

VI. CONCLUSIONS

Good engineering today requires more than technical problem solving skills, a profound knowledge of mathematics and dynamics or an excellent understanding of material behavior or software algorithms. It also calls for a deeper understanding of and a greater sensitivity for the day-to-day situations and contexts in which technological solutions and innovations have to assimilate, and of the people who will use them to live, work or play. If so, then why not go out and explore these contexts and situations, observe those people, talk to them, invite them for design sessions, involve them into the development process etc.

Although contact with the actual end-user might not be so obvious for all engineering disciplines, due to the increased multidisciplinary character of design projects all kinds of engineers have to communicate across different disciplines, and thus have contact with either internal or external users. The techniques presented and discussed in this paper, with some modifications here and there to make them better suited for a specific discipline, could be used as a framework for exploring and investigating the everyday life of these users. Thus it is our strong belief that these techniques and the knowledge, skills and attitude that they bring with them, could be of considerable value to any engineering program.

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Use of E-Learning functionalities: results of a survey along Spain

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Abstract— **This paper shows the results of a survey performed in Spain about the different functionalities of e-learning platforms. This survey was filled in by a group of teachers, experts in Engineering Education along all Spain, through the Spanish Chapter of the IEEE Education Society. The paper shows the opinion on several aspects about the e-learning functionalities, such as knowledge level, usage level, usefulness, etc., as well as the most used platforms. One of the objectives of this work is to create a reflexive debate in the international community about the e-Learning platform use.**

Keywords-component: e-learning platforms, e-learning functionalities

I. Introduction

During the last years E-Learning platforms (Learning Management Systems) have been a new component that have increased their use in Higher Education (as well as in small, middle and large companies) and proliferate in number in the learning applications scenario. The Engineering Education domain has been aware of this tendency and their application in on-line, distance and traditional university education.

An e-learning platform is a software application installed in a web server, which is used to administer, distribute, and supervise the educational activities of an organization or institution. Its main functions are to manage users, resources, and educational materials and activities, to control the access, to supervise the learning process and progress, to make evaluations, etc.

This year 2009, a survey [1] about different aspects on the use of e-learning platforms in the Engineering Education was filled out by the CESEI (acronym in Spanish of the IEEE-ES-Spanish Chapter) group [2]. This group is promoted by the IEEE-ES Spanish Chapter [3] and currently is composed by more than a hundred teachers of 40 universities along Spain, all of them deeply related with the Engineering Education.

This paper shows the most used e-learning platforms in Spain, the main functionalities of e-learning platforms, and the results of a survey about several aspects on these main functionalities, such as (i) Knowledge Level, (ii) Training, (iii) Usage, (iv) Perception of training proficiency, (v) Usefulness, and (vi) Preparation Effort.

Finally, the paper ends with some conclusions and reflections about the results, and the future actions that could be made.

II. E-Learning Platforms and Functionalities

The first group of e-learning platforms considered for the survey were Moodle [4], Ilias[5], Dokeos [6], .LRN [7], Sakai [8], Claroline [9] and WebCT/Blackboard [10]. They were selected according to previous studies, such as [11] and a previous reduced survey on a selected group of users.

The questions on the survey were focused on the usage level of each e-learning platform on each university grade, and on the presential or on-line characteristic of its usage.

With respect to functionalities, they were selected mainly from the Edutools Site [12], works [13][14] and the analysis of functionalities of the previous e-learning platforms.

As a consequence, the following functionalities were selected:

- Content Delivery: It is the most usual functionality, and permits to deliver contents to students.
- e-mail: Internal email is electronic mail that can be read or sent from inside an online course.
- Tasks-Exercises: They usually consist of some kind of material that students have to upload to platform in response to some required activity.
- Forums: Discussion forum is a threaded online text conversation between participants.
- Mailing lists: They allow to send mails to different users in a joint fashion.
- Exams: the typical exams to evaluate the work of students.
- Self-assessment: This kind of tools enables students to assess his/her progress and knowledge level on a specific subject.
- Surveys: This functionality enables the possibility of perform surveys to students on different topics.
- Groupwork: Group Work is the capacity to organize a class into groups and provide group work space that enables the instructor to assign specific tasks or projects.

- Chat: Real-time chat is a conversation between people over the Internet that involves exchanging messages back and forth at virtually the same time.
- Calendar: it enables students to document their plans for a course and the associated assignments in a course.
- FAQs: It is the typical Frequented Asked Questions service.
- Wikis: It is a service that allows the easy creation and editing of any number of web pages, using a simplified text editor.
- Blogs: A blog (a contraction of the term "web log") is a type of functionality that permits an individual to show regular entries of commentary, descriptions of events, or other material, usually in chronological order.
- Glossaries: This functionality allows a way to present definitions that can be looked up by the students.
- Videoconference: It allows two or more locations to interact via two-way video and audio transmissions simultaneously.
- Notebook: It enables students to make notes in a personal or private book. The personal notes can be shared with another students and/or teachers, but private notes can not be shared.
- Whiteboard: Whiteboard tools include an electronic version of a dry-erase board used by instructors and learners in a virtual classroom (also called a smartboard or electronic whiteboard) and other synchronous services such as application sharing, group browsing, and voice chat.
- Learning Paths. This functionality, also called lessons, allows teacher to add entire lessons that guide the student based on the student's answers. It might be helpful to think of a lesson as a kind of flowchart.
- Student Portfolio: Student Portfolios are areas where students can showcase their work in a course, display their personal photo, and list demographic information.
- Podcast: It is a series of audio files that can be downloaded from the e-learning platforms.
- Student Tracking: Student Tracking is the ability to track the usage of course materials by students, and to perform additional analysis and reporting both of aggregate and individual usage.
- Vodcast: It is a series of video files that can be downloaded from the e-learning platforms.

After a period of reflection and discussion, and based on the experience of the working team, we agreed that the questions about these functionalities were: (i) Knowledge Level, (ii) Training, (iii) Usage, (iv) Perception of training proficiency, (v) Usefulness, and (vi) Preparation Effort. We thought that these topics would help us to understand and improve the use of e-learning platforms in teaching/learning processes.

III. RESULTS

The survey was realized during the last days of May and first days of June, 2009. Finally the survey was completed by 162 teachers, where a 79% was male and a 21% was female. The results shown us that only the 13% of the teachers did not use e-learning platforms, and the rest (87%) did use them.

The characteristics of the teachers can be seen in figures 1, 2 and 3. Figure 1 shows the distribution of teachers according to their age. It can be shown that there practically all ages are represented, and that the most of them are in 36-50 range (63%). Figure 2 shows that the 45% of teachers has more than 20 years of teaching experience, and that more than the 50% has more than 15 years of teaching experience. Finally, figure 3 shows that more than the 60% of teachers who use e-learning platform has at most 5 years of experience in such platforms.

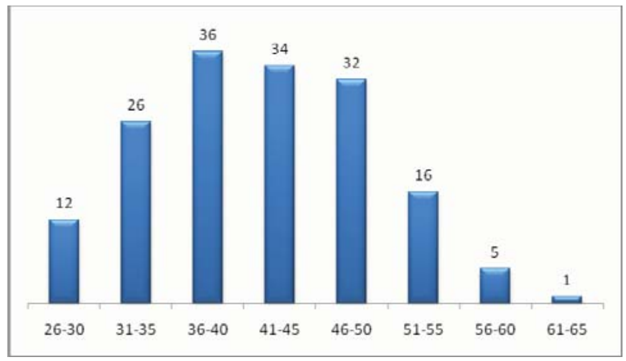

Figure 1. Distribution of teachers according to their age.

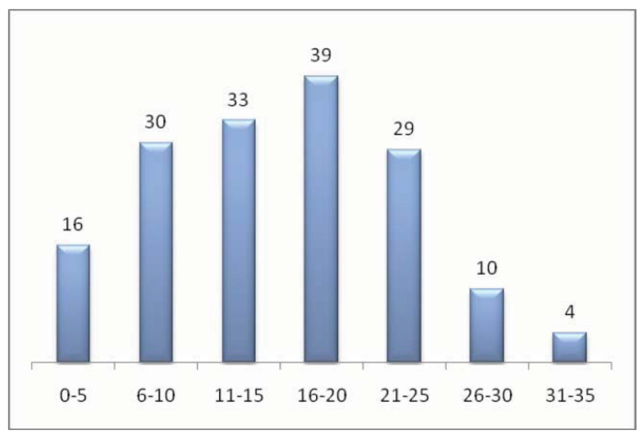

Figure 2. Distribution of teachers according to their teaching experience in years.

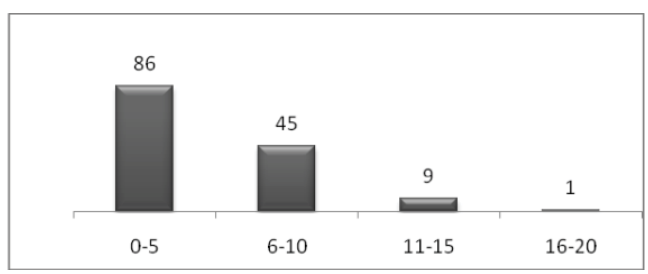

Figure 3. Distribution of teachers according to their e-learning tools experience in years.

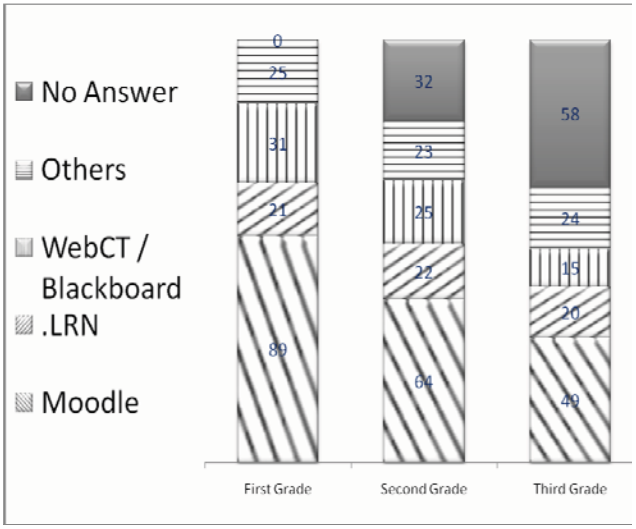

Figure 4. Distribution of e-learning platforms according to grade.

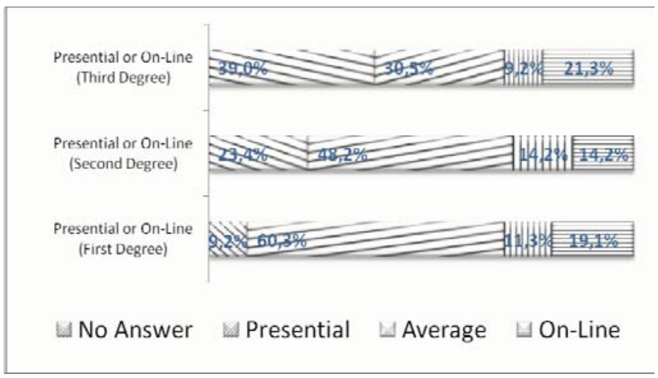

Figure 5. Presential versus on-line use of e-learning platforms.

In the figures 4 and 5 we can see the most used e-learning platforms in Spain according with the university grade (first grade or diplomate studies, second grade or graduate studies and third grade or doctoral studies), and the presential vs. on-line use in each grade. Notice that Moodle [4] is clearly the first used e-learning platform in all grades, and that WebCT [10] and .LRN [7] are both quasi-equal in the second place. Among the others e-learning platforms used in Spain are proper university platforms (6 cases), Aula Global (3), Aula Web (2), ACME (1), eKASI (1), ecampus (1), SIFO (1), ADI (1), SWAD (1), MIT (1), GEN (1) and Drupal (1).

With respect to the use on-line or presential, we can emphasize that the character on-line is between 14% and 21% in the three grades, and the character blended learning (mixture of on-line and presential) is between 9% and 14% in the three grades. However, the character presential significantly decreases with the grade, from the 60,3% in first grade, to 48.2% in second grade and finally to 30,5% in third grade. It is also significant that a greater grade, the greater the teachers who do not answer to this question.

In figures 6, 7, 8, 9, 10 and 11 (last pages of the paper), the results for each one of the topics and functionalities selected in this paper are shown:

i. With respect to the Knowledge Level of these functionalities, we can see that there exists a group of functionalities with a high degree of knowledge (greater than 50%): Content Delivery, e-mail, Task-Exercises, Mailing Lists, GroupWork, Surveys, Exams, Self-assessment and forums. On the other hand, there exists a group of bad-known functionalities (low or no knowledge greater than 50%): Podcast, Vodcast, Whiteboard, Notebook, Student Portfolio, Learning Paths, and Student Tracking.

ii. With respect to the Training received for each one of the functionalities, we can remark that in general it was scarce: there is no functionality with a high level of training greater than 25%. This is one of the more interesting results of the survey: the missing training.

iii. Figure 8 shows the Usage Level, and we can see that Contents Delivery, e-mail, forums and task-exercises are the most outstanding functionalities (high level greater than 50%), while whiteboard, videoconference, student portfolio, learning paths, podcast and student tracking are the less used (not used). If we add mailing lists, Groupwork, surveys and exams to the most outstanding functionalities, the rest of functionalities are rarely used.

iv. Figure 9 shows the perception of training proficiency for each one of the functionalities, and confirms the results of topic ii. There is a general perception of lack of training.

v. Figure 10 shows the perception of usefulness of the different functionalities. The most outstanding (with a high level of usefulness, greater than 50%) are Content Delivery, e-mail, mailing-lists, Groupwork, Surveys, Tasks-exercises, exams, self-assessment, and Forums. On the other hand, the less useful (denoting no or low useful with a level greater than 50%) have been Student tracking (the only functionality with a level of no useful greater than 50%), Podcast, Vodcast, Notebook, Student Portfolio, and Learning Paths.

vi. Figure 11 shows the preparation effort for each functionality. This topic must be considered with care, and taking into account the results of the other topics, specially the usage level. If one functionality is not used, obviously its level of preparation effort should be null. Therefore, it can be shown how the results for the less used functionalities are also the lowest in this topic, and the most used functionalities have a relative high preparation effort level, such as content delivery and task-exercises. However other most used functionalities such as e-mail and forums have not a relative high degree of preparation effort.

IV. CONCLUSSION

In this paper we have showed the results of a survey realized in Spain about the e-learning platforms functionalities.

In short, there are two main conclusions: (a) first of all, the most used e-learning platform in Spain is clearly Moodle[4]. And in second place, and in our opinion the main conclusion of this survey, (b) it is the lack of training in the different functionalities. Therefore, it is apparent that there is a need for training on the different e-learning functionalities. If we compare the set of functionalities where the teachers have less level of knowledge (topic i), of usage (iii) and perception of usefulness (v), then we have always the following functionalities: Podcast, Vodcast, Student Portfolio, Learning Paths, and Student Tracking.

We think that the different Spanish universities have to increase the training of university teachers not only on these functionalities but also on the different methodologies linked with them, in order to obtain the best use of all of them.

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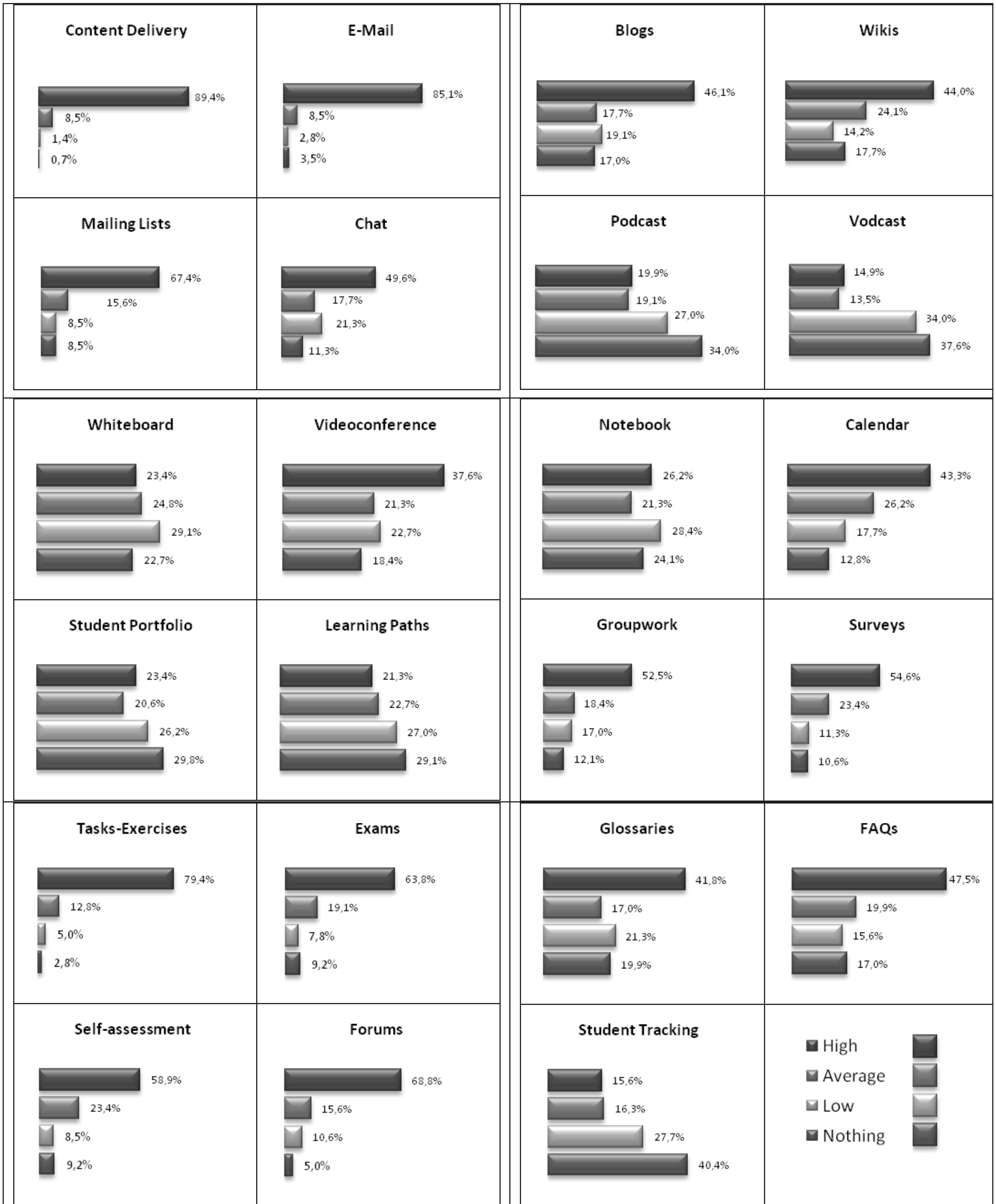

Figure 6.- Knowledge Level

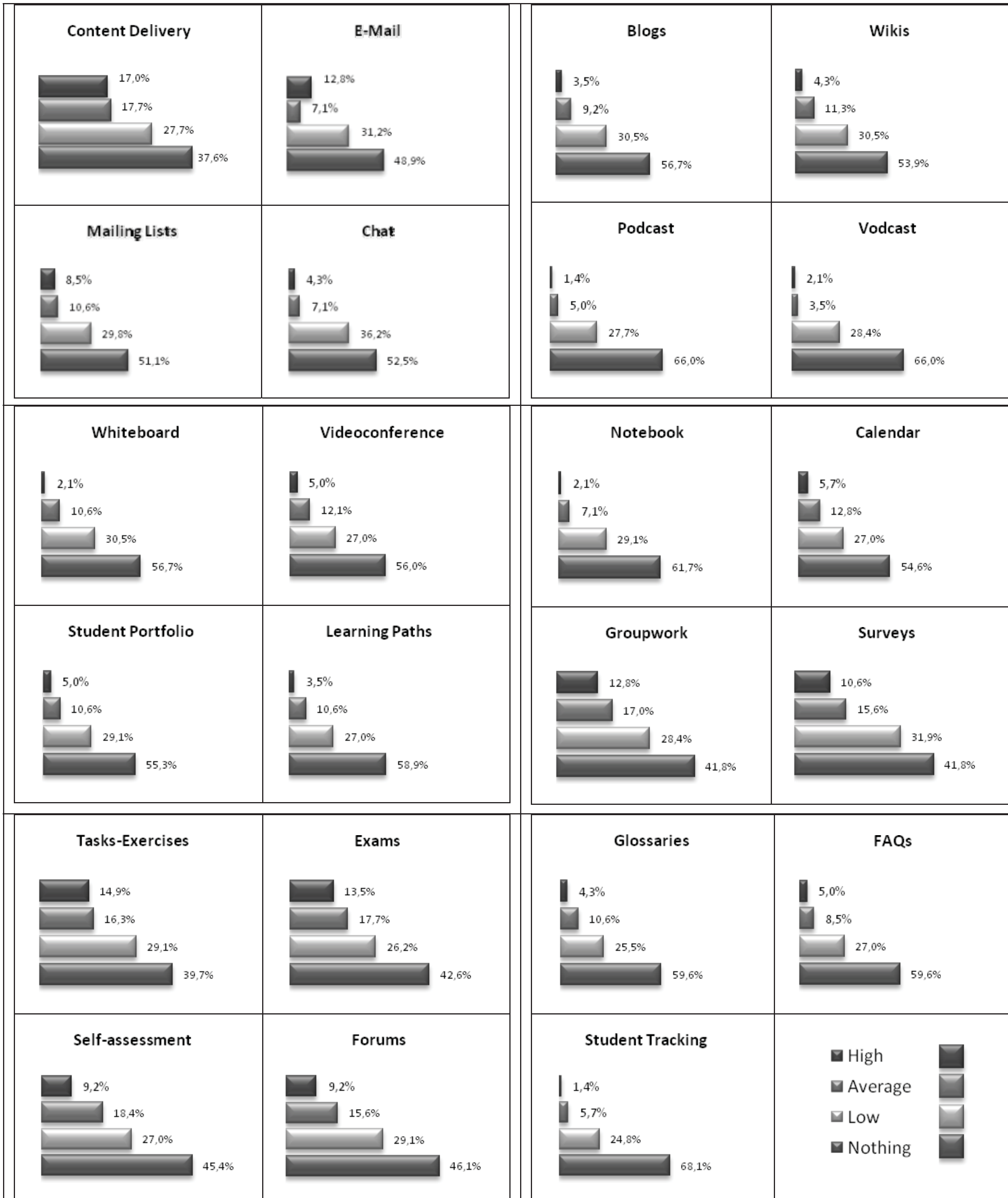

Figure 7.- Training

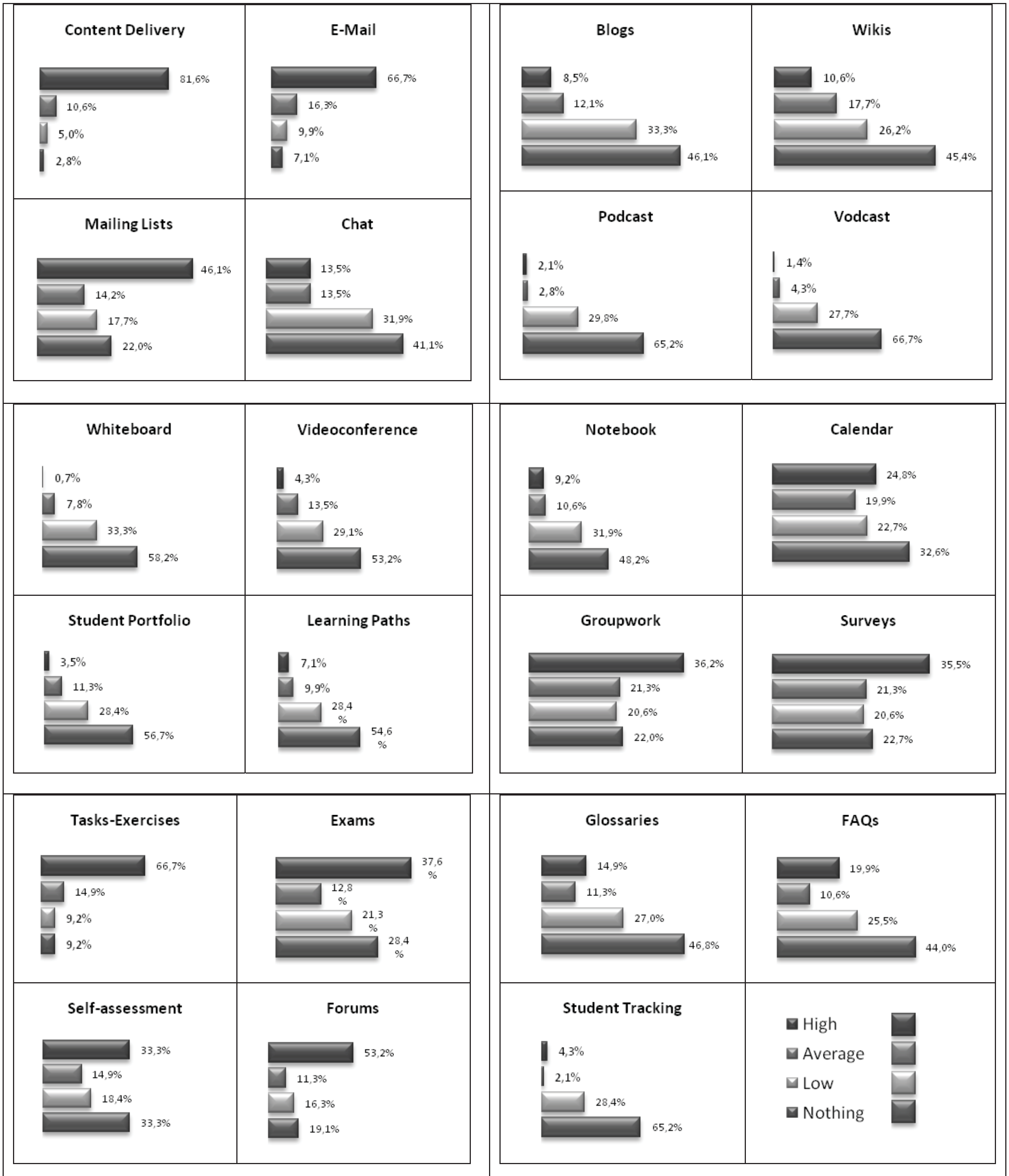

Figure 8.- Activity Usage

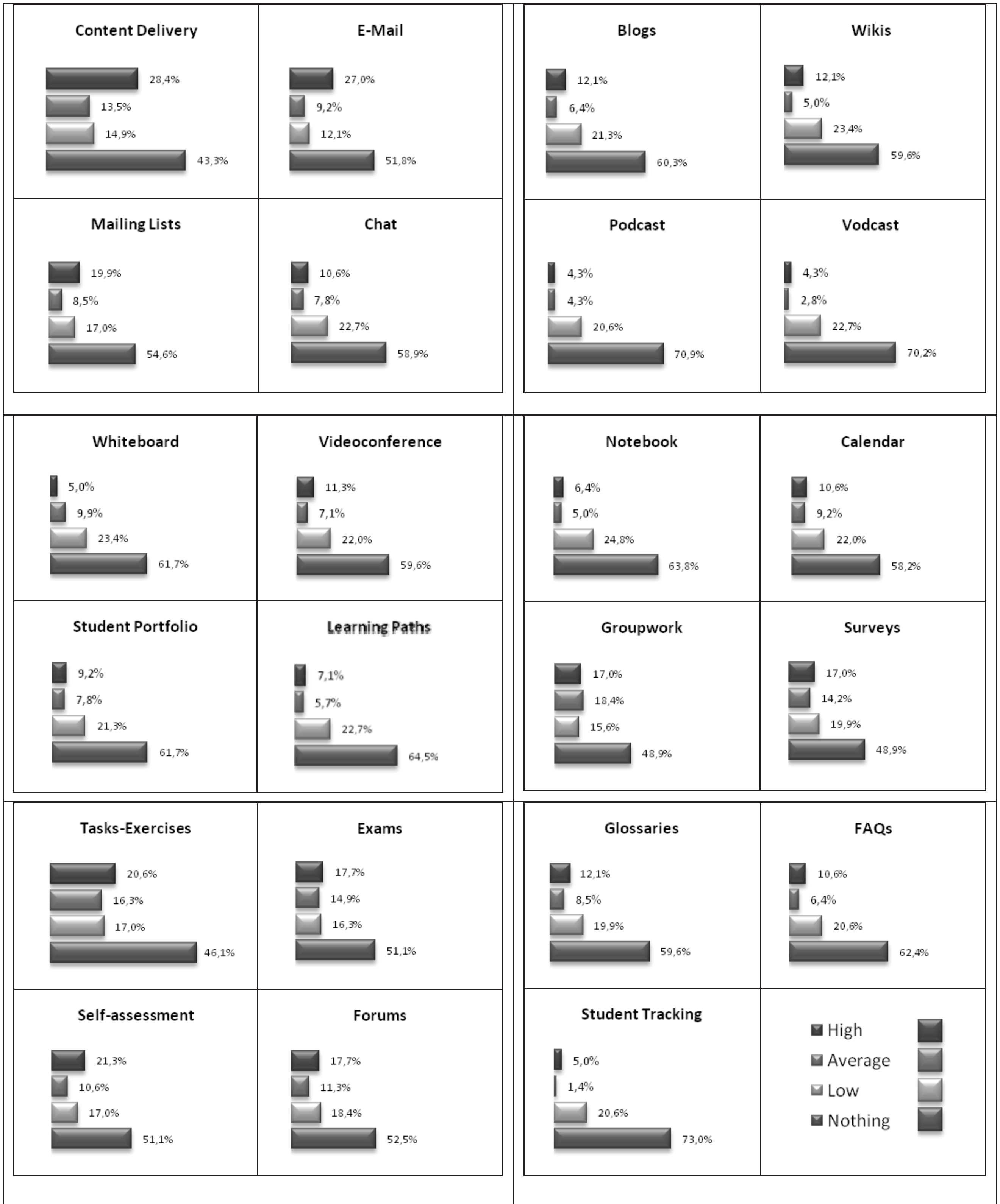

Figure 9.- Perception of Training Proficiency

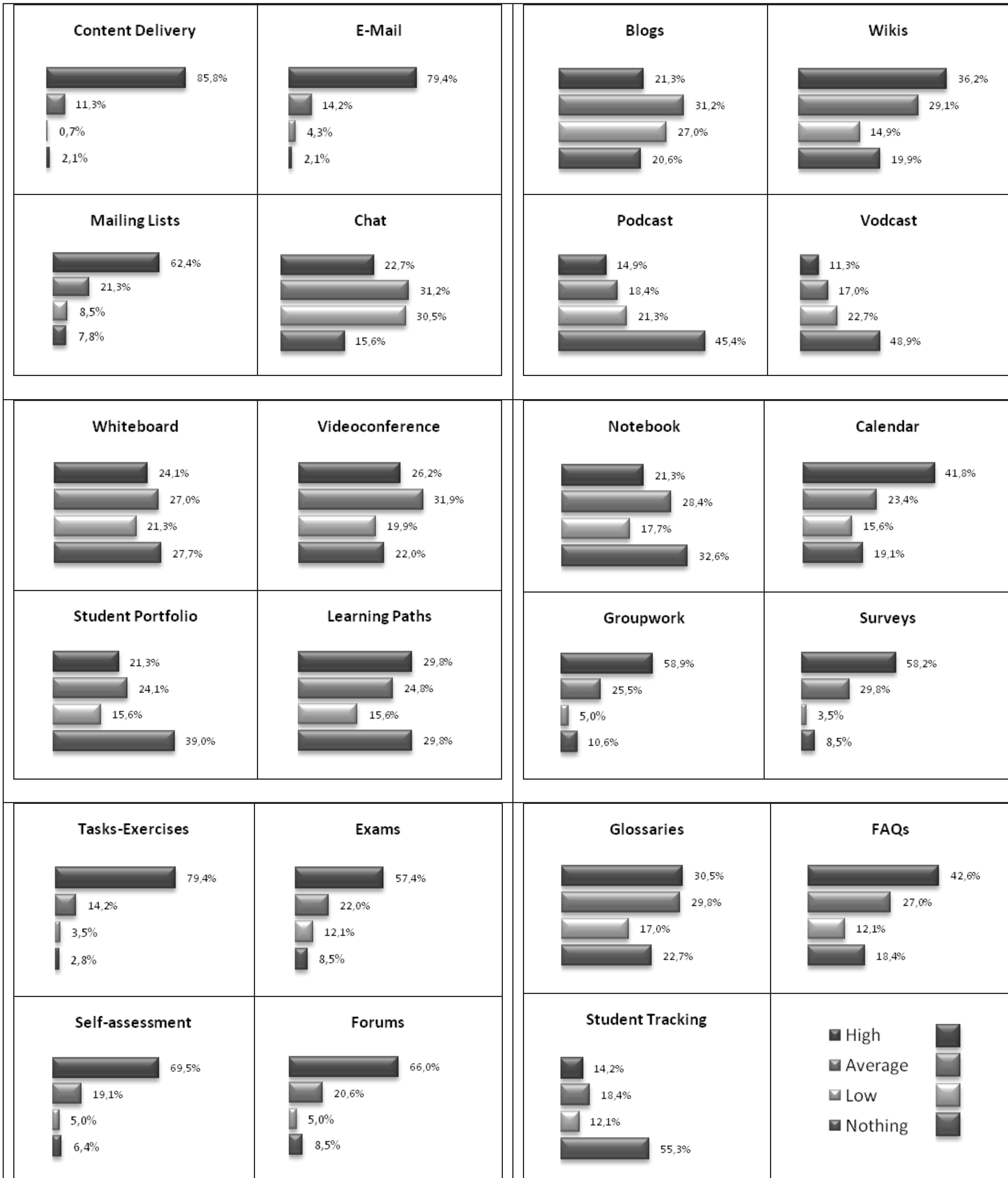

Figure 10.- Usefulness

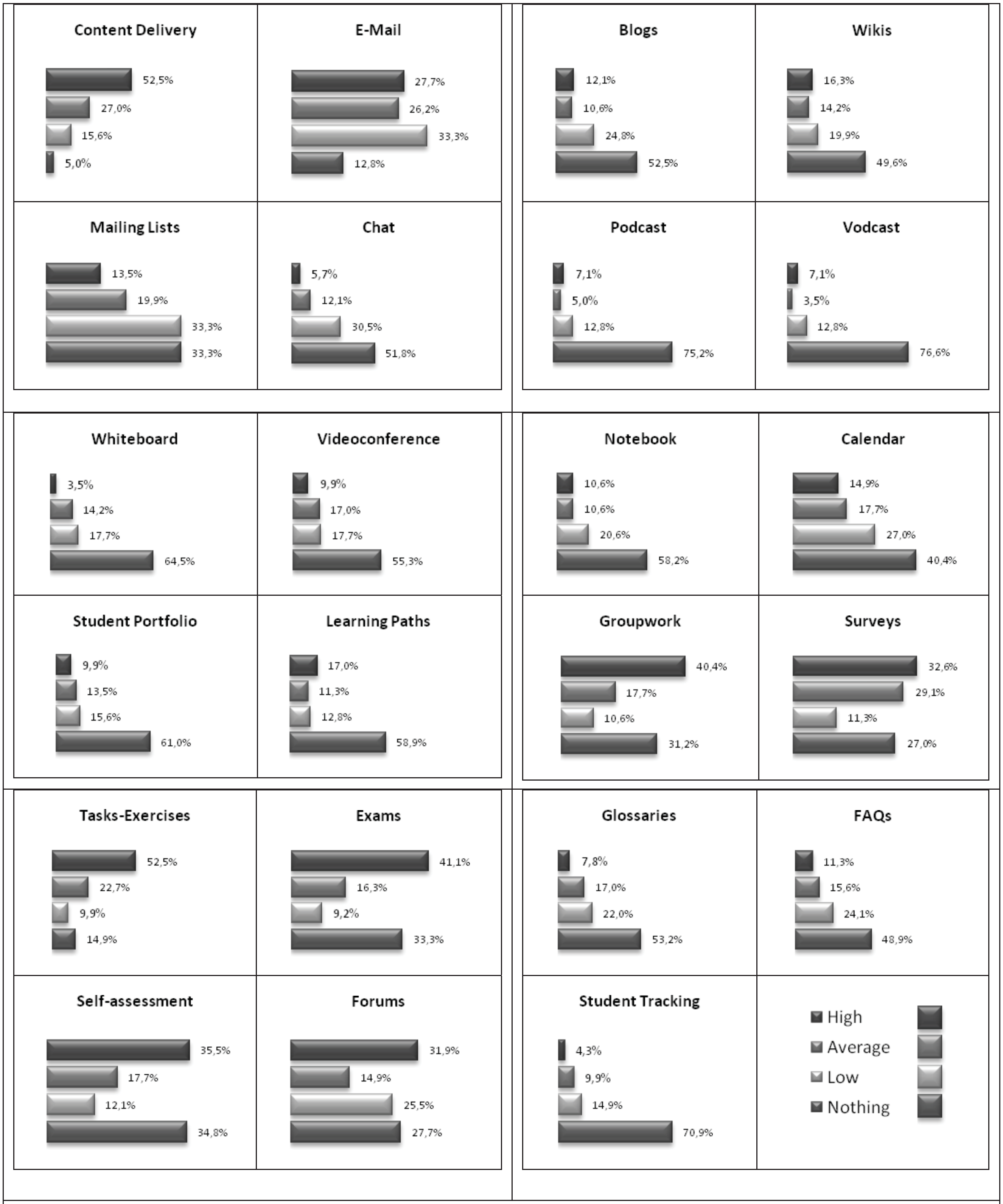

Figure 11.- Preparation Effort

Active Learning in Power Electronics

From classroom to laboratory

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Abstract— **Changing the paradigm from lecture teaching to student learning an experience has been successfully carried out in a 3rd course in the degree: there will not be lecture sessions or lab sessions any more. Students go directly to laboratory and the sessions take place on guided experiments about each analyzed topology in the syllabus. So theoretical analysis, modeling and simulation and experimental results of power electronics topologies are carried out together by students in an active learning methodology. The facilities have been disposed in a suitable way in order to become it flexible and have got a wide set of equipment that allows to perform lecture sessions, modeling and simulation skills, web based activities or lab experiments. Moreover, a professional power systems simulation tool with limited license is offered to each student in order to support his learning process at home same as that in classroom.**

Keywords- laboratory, methodology, Power Electronics.

I. Introduction

The University of Cordoba (UCO) and its Higher Technical College (HTC) have carried out many experiences along the last seven years with the aim of adapting teaching methodologies, guides and subject programs to the European Higher Education Area (EHEA), and more specifically, to the European Credit Transfer System (ECTS).

The University of Cordoba has supported methodological innovation and improvement by means of its own Teaching Innovation and Improvement Projects Program for the last ten years [1]. This program supports financially the purchase of the needed media, materials and equipments to develop all the approved activities and provides experienced supporting personnel to help us meanwhile them are carried out.

Four years ago, one of these projects (related to a non compulsory subject on Power Electronics) included a partnership contract with Powersys Ltd. in order to obtain the needed student licenses to help the Electronic Power Systems learning [2] [3]. As a consequence, all of our students are provided with a license of PSIM® for their scholar life. This professional power systems modeling and simulation tool is one of the basis of self-learning procedures carried out in the subject referred at this paper. It is used both for explaining the power systems function and for making simulation experiments both at university facilities and at home. Even this simulation tool is able to be used in many other engineering subjects in the degree.

Once financial problems (the major nemesis on any change action) have been solved, methodologies and teaching paradigm have to be revised and updated to self learning procedures and experience based learning.

II. Active learning principles

Active learning focuses the responsibility of learning on learners and comprises a wide set of methodological activities and experiences. Active learning activities include, for example [3]:

- Think-pair-share activities. Learners ponder a previous lesson, later to discuss it a little group of their mates, finally to share it with the class in a formal discussion. The instructor should clarify misconceptions during this last stage. However students need a background in the subject matter to converse in a meaningful way. So, this exercise is useful in situations where learners can identify and relate what they know to others
- The learning cell gets a pair of students together to study and learn. First they read the assignment and write down questions that they have about the reading, after students alternate asking and answering questions on commonly read materials during the learning process. At the next class meeting, the teacher will merge new pairs randomly and the students will asked their own questions to each other alternatively. During this time, the teacher is going around the class from group to group giving feedback and answering questions.
- Class discussions that may be held in person or in an online environment. This environment allows for instructor guidance.
- Short written exercises are a good way to review materials, the better if they are proposed as worked-examples.
- Teaching the new contents to each other at class at a studying or working group or by means of a forum or a wikiplace. Anyway students have to be closely guided by teachers.

In our opinion, the first activities related are more formal than the last ones and requires a more structured teaching procedure. So they are more complex to be carried out. Discussions, short exercises (guided or proposed), and peer teaching are in fact more flexible and allows the teacher to adapt the learning flow to learners. Anyway, as seen in the aforementioned activities, in order to ensure efficient instructional strategy teacher guidance must be an essential part of active learning. Moreover, practice after initial learning is of vital importance in student's education. Its importance lies on the fact that students who practice discovery learning are more likely to recall information.

Many activities described before are able to be applied to experiences in a discovery learning way. Learners work in pairs during lab sessions, discuss materials while role-playing, debate, engage in case study, take part in cooperative learning, or produce short written exercises, etc. As can be seen, the whole set of activities related to active learning are used meanwhile lab experiences are carried out.

The reinforcement of learning lies on practice, discovery activities and application problems. But this last one is not always suggested specially if the matter is their first approach to a subject in the syllabus. Guided or worked-examples could then be the best choice.

III. DESCRIPTION OF THE EXPERIENCE

Some previous experiences on active learning in Electronics are almost exclusively focused on simulation [4], multimedia [5], remote labs [6] or CAD tools [7]. However, other active learning education experiences include a wide variety of activities that fit with the aforementioned principles, as in [8]. The work described in this paper matches this profile. The experience is carried out in a noncompulsory subject in the 3rd (currently the last) course in the degree of Industrial Technical Engineering, specialty in Electricity. Traditional methodology of lecture sessions and laboratory or simulation sessions has been suppressed and they have been joined in a holistic learning process [3].

A. Facilities

Students work in laboratory facilities in which lab places are distributed likewise a lecture room. The advantages of both teaching methodologies are then focuses together to improve learning. Each place in the lab is equipped with a desktop PC connected to the Internet, adequate electronic instrumentation, 3-phase 24/42/230/400 V_{rms} and DC supplies and a set of power converters adapted to educational purposes. A lab overview can be seen at Figure 1. Figure 2 shows a detailed a pair of sights of the specialized equipment in a lab place. Thus, students have means enough to a classic lecture session, to model and simulate a power system, to experiment with the lab modules, to access to the internet and the learning resources sited there or to cooperate each other.

On the other hand, teacher's place is provided by an interactive smart screen. The teacher has access to every lab place personal computer from his place. So any situation that can occur can be shown to the classmates who can give their opinion and discuss the posed problems.

Figure 1. Laboratory overview

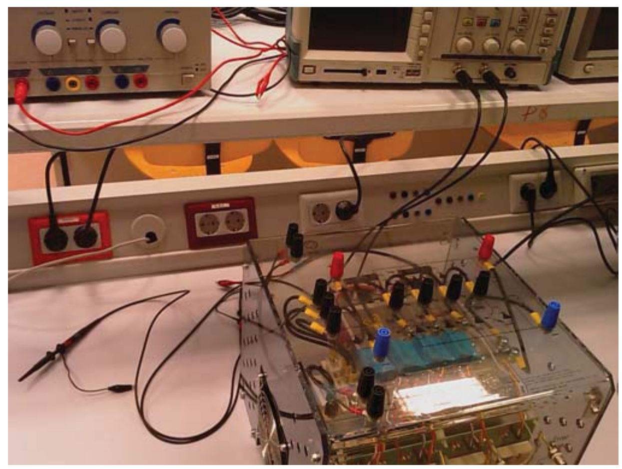

Figure 2. Lab places in detail

B. Learning Virtual Platform

Theoretical principles are at students' disposal by means of the e-learning platform UCOMoodle®. UCOMoodle® is an evolution of Moodle® developed at our University. Figure 3 shows the subject main page. Links to java applet simulations, data sheets of electronic devices, slides, presentations, etc. are also offered in all studied cases. So, the materials disposed give the source of knowledge background needed to active learning activities.

Figure 3. Subject main page at UCOMoodle

C. Modeling and simulation tool

Powersys Ltd. and the University of Cordoba have a partnership contract since 2005. As a consequence an unlimited number of student licenses of PSIM® software. So, All the students fro the UCO can request a student license for their scholar life due to a partnership contract between Powersys Ltd. and our University. This professional tool is able to be used for modeling and simulating power electronic systems and control, function and programmed blocks, electrical machinery, instruments and sensors and a wide variety of loads as well. It is a helpful resource both for explaining the power systems function and for making simulation experiments both at university facilities and at home.

In the presented experience, its use is restricted to analyze the behavior of the most common used power electronics topologies and to model the basis of their control modes. It also can be used in order to prepare the sessions, check the results of analyses or prepare for solving non guided cases at their convenience.

Figure 4 shows one of the analyzed topologies: A DC motor drive fed by a Buck converter with a speed control loop

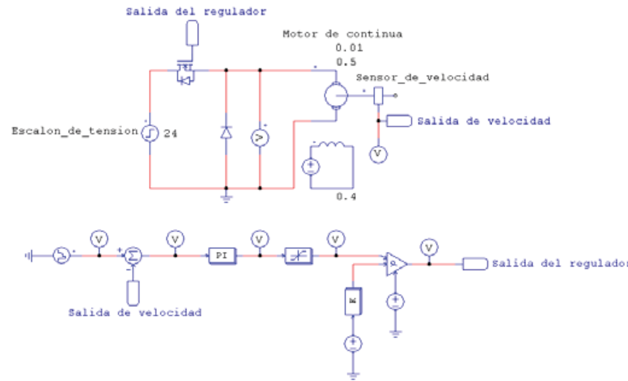

Figure 4. An example of the analyzed power systems

D. Working at classroom and homeworking

The class process starts with a brief introduction on a focused matter. Principles of operation of the about power topology and its basic control techniques are then explained and some worked-examples are discussed and developed for students as a class exercise or homework. Question and answers flow to each others after a think-pair-share activity or like a class discussion way. This takes place first at classroom and at a discussion forum guided by the teacher at UCOMoodle® later.

Students have to analyze and solve more complex problems after the exampled are done. They calculate the appropriate parameters of the topologies studied, model the circuits and simulate then using PSIM®. This autonomous work is done in a kind of learning cells. Another forum site at UCOMoodle is offered for sharing experiences, problems and solutions during this job.

All the collaborative activities of learning by teaching strategies at the virtual learning framework are supervised and valued by the teacher and its marks included at student studio assessment.

A set of lab sessions are done along the semester once theoretical behavior are know and operation modes have been analyzed. During its implementation a form about the experience has to be filled in and some short written exercises related with experiment functionality and lab procedures are done.

The evaluation of the acquired knowledge and competences includes a summary of the labs exercises done and a more complex analysis case than included in the syllabus. Students have to expose their work too and answer any question asked by the teacher or their classmates at the examination session.

IV. Results

This methodology has been carried out in several non compulsory power electronics subjects in the syllabus by the group of teachers aforementioned at authors' field. An average of twelve students (between six and twenty students) has been attended in these subjects. Lab facilities can be employed by up to twenty four students at the same time.

Presence rates have been improved in all cases up to almost the 100% across the last four years. The success rate didn't change significantly but marks have grown for all the students.

Satisfaction surveys within our quality control system show an important approval of the adopted methodology. Unfortunately we are not authorized to show any of these quality index data.

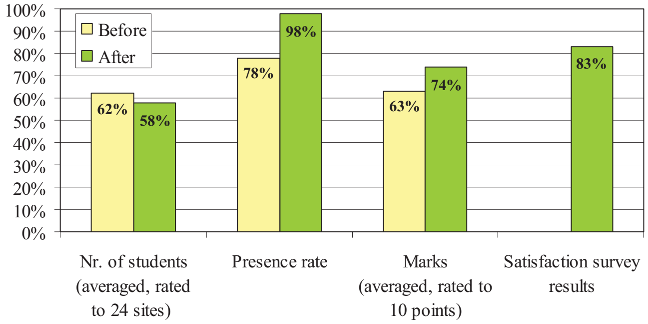

Figure 5. Comparison overall rates before and after adopting the presented methodology

V. CONCLUSSIONS

An active learning methodology has been planned and successfully carried out, including a wide set of proposed activities. Lecture sessions, simulation exercises and lab experiments are able to be given at the same place and at the same time without any break in continuity. Students have welcomed the experience for the last five courses and their marks have significantly improved. Absenteeism is negligible.

ACKNOWLEDGMENT

Authors thank the UCO for its supporting program that aims to methodological improvement.

Authors also thank Powersys Ltd. for keeping the aforementioned partnership contract for the last four years.

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Learning engineering by teaching engineering in the European Higher Education Area.

Video engineering approach.

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Abstract— **Even though active learning is not a new trend in engineering education, different schemes based in "learning by doing" are being proposed every day in the engineering education community. Considering "teaching" a topic to be a learning activity it can provide profound learning outcomes. A course previously adapted into an active learning environment has been reshaped to let the teaching experience to take place as a learning situation.**

Keywords-active learning; learning by teching; engineering education.

I. INTRODUCTION

The arrival of the European Higher Education Area and the re-design of University degrees have become a big challenge. The new degrees will start their implementation in September 2010 at the University of Alicante. Even though there are experiences in which competences-based education is a reality, the uncertainty feeling is inevitable. In this environment, engineering teaching-learning strategies are immersed in a constant evolution worldwide. The case of European Universities is especially noticeable due to this convergence process. The main goal of our task as educators is to provide with students an environment in which learning may happen. The active role of students is now a must to reach the new quality standards. Even though active learning is not a new trend in engineering education, different schemes based in "learning by doing" are being proposed every day in the engineering education community. There is no doubt about the benefits of "doing" as an effective learning tool applied to engineering training. Nevertheless, by itself, doing can not ensure effective learning to take place. A further reflection of what and why has been done is compulsory to transform the information into knowledge. In fact, there are several "doing situations" in which learning appear to be more exhaustive. Let us think, for instance, in the learning outcomes derive from our own teaching experience.

Teaching a new topic, or course, for the very first time is a profound learning situation. Any educator will agree considering her or his first classes as a high-level learning situation. Besides, within this teaching environment, assessment provides a valuable generation of feedback and reflection. Making students be involved in such an environment (peer-teaching and peer-assessing) will let them into a favorable and very effective learning opportunity for both trainer and trainee.

With these principles in mind, a course previously adapted into an active learning environment has been reshaped to let the teaching experience take place as a learning situation. Course activities try to persuade that some of the students will act, at certain moments, as trainers of a group of colleagues being trainees. Roles will change at different activity stages so that all students will have to be the trainer sometime.

Regarding the assessment, students will have the opportunity of getting feedback and high level reflection about the concerning subjects by means of peer and self assessment.

Besides, working in a particular course designed into an active learning environment, including learning by teaching will get not only academic but transversal skills improvement. Issues as group working, communication skills or liability are managed as good as engineering or scientific skills.

After a five-year process of adaptation of the learning model concerning the courses "Video Engineering" and "Video Laboratory" from conventional to active style, a considerable set of activities have been generated. Both courses present high realistic engineering contents, making them an interesting environment of professional-like engineering training experience.

Although Video Engineering and Video Laboratory are third year courses in Telecommunication Technical Engineering (BSC), single or sequences of activities have been exported to other compulsory and optional courses inside both Telecommunication and Computer Science degrees. The possibility of exporting any particular activity or sequence of activities to other disciplines will provide a wider range of benefits, promoting improvement in these other courses. This process has been carried out to provide other professors an easy way to adapt one particular activity or a sequence of activities focused in Video Engineering to their own disciplines. One of the main outcomes of the project was the interchange of activities between courses trying to make extensive the application of the methodologies designed.

II. TEACHING SITUATIONS

Video Engineering is a third year course in Telecommunication Technical Engineering (BSC), with sound and image speciality. It is a compulsory course included in two of the three program branches considered at the syllabus. The duration of the course, as established at the curriculum, is six theory credits and three practical ones, with one credit considered as ten hours attending class. Video engineering is a discipline with a high degree of engineering based development. The course main goal is formulated by one general objective: to train engineering work characteristics by means of studying video systems. Some of the competences explicitly presented include group working, communication skills and complex problem analysis. For that reason, it can be suitable for using problem based learning (PBL) [1] boarding the different aspects as if the students were the engineers trying to find the answer of a particular technology problem. This will be the approach of all activities performed along the course, taking into account the constraint of slowly increase their level of complexity. Besides, a series of short research projects is included within the course, resulting in a methodology combining project [2] and problem based learning. A more comprehensive course description can be read in [3].

Summarizing, the course is structured into an active learning scheme. Nevertheless, if students' degree of motivation is not high enough it is not easy to maintain the required working level to success in the course. An interesting strategy to let students reach a high level of motivation can be found in the "ripples model" presented in [4]. This model states the main factors and their relationships underpinning true learning situations. These five factors can be declared as: 1. wanting to learn, 2. needing to learn, 3. learning by doing, 4. learning through feedback and 5. making sense of what have been learned. Teaching a new subject is, among others, an experience in which all five factors are present, so it can be assumed to be a true learning situation.

The adaptation of Video Engineering course into an active learning scheme began in 2003 with a pilot test. Since that time a continuous evolution have been carried on, introducing changes in course structure, contents, methodology and assessment. From 2005 the course can be considered to be fully implemented into an active learning scheme based on cooperative learning, problem based learning and project based learning. Students are organised in small working groups, performing a sequence of activities preceded by short introductions and followed by discussion facilitated by the professor. With this starting point, it is not difficult to reshape some of the activities with the aim of making teaching a conscious part of the course.

The project hypothesis can be stated as: "making students play teacher's role puts them actively in a "wanting and needing to learn" situation based on a high degree of motivation". Some measurable results of this motivation are expected in terms of improvement of the academic results and reduction of the number of drop-outs, as these two items are widely considered as some intrinsic problems in engineering education [5]. Even though Learning by Teaching is not a new trend in education, it has been basically used in language learning [6], [7]. The goal of this work is not to get an adaptation of previous learning by teaching schemes to engineering education, but to emphasize teaching opportunities in an engineering course adapted following active learning models.

It is important to state that all the referred teaching situations are preceded by a working stage following the designed sequence of activities. We are not making students just to explain part of the syllabus to the others. All the teaching situations follow a previous reflection stage ensuring the expected learning outcomes.

The following sub-sections will describe some of the learning situations generated in the course. The goal is not to make a comprehensive description, but to present the basic ideas supporting the teaching-related activities.

A. Course goals statement

If one wants students to feel responsible of their learning process, they really have to be responsible. The first designed activity of the course is performed to let students to state course goals. If students are working what and how they want to, motivation is guaranteed.

B. Explaining contents

Group working activities lead easily to explaining-related situations. Taking into account some basic rules of cooperative learning will ensure that, at specific moments, all group members will have to act as teachers explaining their group-mates part of the course contents.

Besides, the project based sections of the course facilitates a major challenge, making students to explain their research results to the remainder of the group (Fig. 1).

Figure 1. Student presenting research results to the remainder of the group.

C. Tutorizing laboratory work

Laboratory work in video engineering is not easy to organize. The laboratory is equipped with broadcast-quality video production elements representing realistic professional working configurations. Due to the high cost of the laboratory equipment, there is only one working station of each configuration, so each cooperative group is working in a different station. Every week, each group has to be able to become familiar with a different, new and unknown working station. Having up to 12 groups trying to figure out how a new, and different for each group, system works can be difficult to manage. To avoid this situation to become chaotic, some students act as tutors of any configuration (Fig. 2). Each group has had extra time at the beginning of the semester to become experts of one of the available working stations. This system generates benefits in two ways. Not only students are teaching mutually, but the problems of the groups can be solved more eficently.

The system is implemented so all the students will have to play tutor's role during course semester.

Figure 2. Student playing the role of peer-tutor.

D. Assessing

Possibly, the activity demanding a higher level of responsibility is the assessment. Having to assess some other's work implies a profound knowing of the matter and a serious stage of the "learning by feedback" and "making sense" ripples presented earlier in this section. Students will have to perform peer and self assessment activities at different course stages.

III. RESULTS

Course design results are measured using both quantitative and qualitative indicators. Quantitative indicators are the students' academic results summarized in their final marks and the analysis of the number of passing and abandoning students through the course. Qualitative analysis is based upon questionnaires designed to get students' opinion regarding different course aspects.

Fig. 3 presents the evolution of the average final mark of the whole group from 2002 since 2008 and its standard deviation.

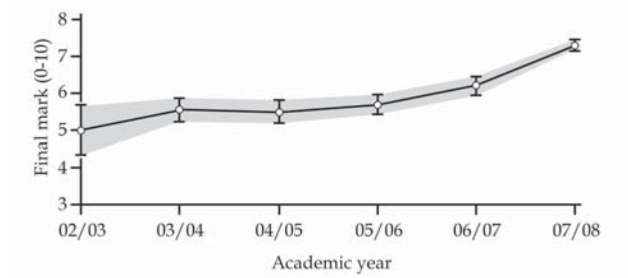

Figure 3. Evolution of the average final mark in a 0-10 scale and the standard deviation between 2002 and 2008.

As the course methodology has been changing, assessment has been evolving as well. The assessment is actually performed as a combination of several evaluation activities combining self, group and peer assessment and a final exam. A more detailed description of the assessment procedure can be found in [8].

This analysis period has been chosen as in 2002 the course was still implemented in a conventional methodology based on lectures, laboratory and problem solving sessions. The first pilot experience of active learning approach was carried out in 2003, and the teaching-based activities were introduced in 2007.

The results derived from Fig. 3 are quite interesting, as they show a clear ascent tendency, from 5 to 6.9 points in a 0-10 scale. It is also significant that the standard deviation decreases as the average value increases, meaning not only an improvement on the academic results but also a more coherence between students.

There is no direct indicator to measure if the introduction of teaching activities has impact in the motivation of students. Nevertheless, thinking of motivation as an effect of the "wanting to learn" and "needing to learn" ripples, a relationship can be assumed to be between the presence of that ripples and the number of students abandoning the course. An increase of the degree of "needing" and "wanting" ripples will cause a decrease of the drop-outs. Fig. 4 presents the evolution of the number of abandoning and passing students in the analyzed period. It is remarkable the difference in figures between the first year (traditional teaching scheme) and the other ones. In 2002 the number of abandons was near to 50% of the students. On following years this figure clearly drops below 20%, surprisingly arriving to 0% on 2007.

Moreover, the conclusive data about drop-outs is followed by an ascent slope passing students curve, going from 60% to more than 85%.

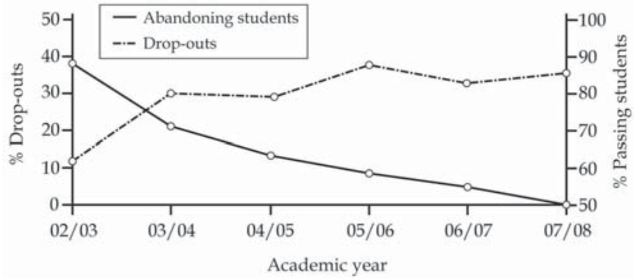

Figure 4. Evolution of number of drop-outs (left axis) and nunber of passing students (right axis) between 2002 and 2008.

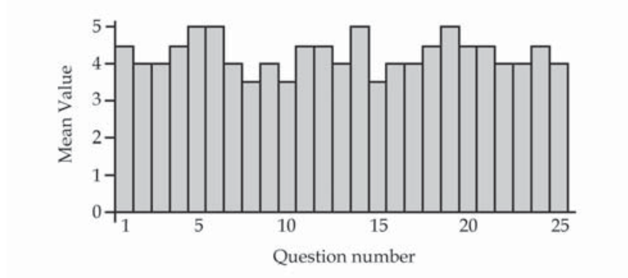

Figure 6. Mean value of the answers to the course evaluation questionnaire regarding 2007/2008 course.

Besides the numerical results, some qualitative data have been obtained using custom designed questionnaires. The aim of such questionnaires is to get students' opinion concerning particular aspects of course structure, such us contents, general methodology, group working tasks, and so on.

The questionnaire is composed of a set of sentences that students have to mark their degree of acceptance. The answer is coded in a 0-5 scale, in which 0 means "absolutely in disagreement" and 5 "absolutely in agreement". One of these sentences that students may (or not) agree with states "I have the impression of being learning", relating to the self awareness of the learning process. Fig. 5 shows the mean value of the answers to this sentence in the 0-5 scale previously presented. The degree of agreement with this sentence is especially significant, as it relates, not only with students' responsibility towards learning, but with being actively conscious of the learning outcomes derived from a particular set of activities.

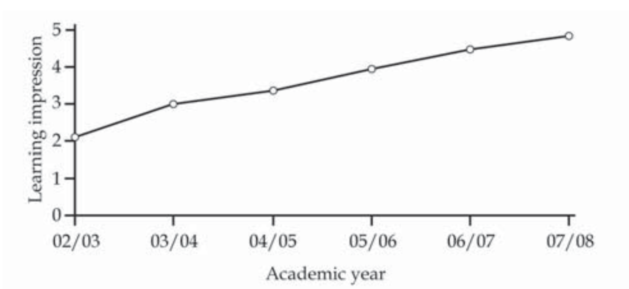

Figure 5. Evolution of the mean value about "I have the impression of being learniong" sentence between 2002 and 2008.

The full questionnaire consists in 25 coded questions plus five more open answer questions to let students freely express their opinion about the course. Fig. 6 presents the mean value of the 25 questions, rounded in 0.5 steps, regarding 2007/2008 course.

The topics included in the questionnaire are both general and specific ones about different course aspects (goals, contents, methodology, assessment…). Without pretending to perform a highly detailed analysis of the results, it is clear that students' general opinion about the course is quite positive. As the questionnaire has been designed just for Video Engineering course, it is not possible to compare results with other courses. Notwithstanding, it can be said that the general results have been improving following course evolution.

Considered as another interesting outcome, the possibility of exporting any particular activity or sequence of activities to other disciplines will provide a wider range of benefits, promoting improvement in these other courses. The methodology adaptation process carried out in the Video Engineering course during the last four years has generated a considerable amount of single activity and sequences of activities. Up to date, the activity migration process takes place unidirectionally, from Video Engineering to other courses. This fact is due to having in mind the possibility of migration as one of the design basis. The courses actually using activities from Video Engineering are Digital Electronics (firs year compulsory course in Telecommunication Technical Engineering), Broadcast and Cable Television (third year optional course in Telecommunication Technical Engineering) and Multimedia Techniques (third year optional course in Computer Science).

In addition, as a final quality indicator, a test was performed by the end of the first semester in the 2007/2008 academic year in a randomly selected last year course of the degree. The random aspect was included to unlink the answer of the test with any particular course. Students were asked to write down the two courses in which they had the impression of being learned more. There were two most rated courses selected clearly among the others, with similar marks. One of these courses was Video Engineering, while the other is one of the courses actually adapting some of the sets of activities designed for video engineering.

IV. CONCLUSION AND FUTURE WORK

Active learning schemes are widely considered as suitable methods to be used in engineering education. Nevertheless, it is possible to improve the results of the learning process going further than just "making students to do things". Complementing the "doing" factor with elements ensuring that students are conscious of their own learning process (they have evidences of how they are learning) improves course outcomes. One of these factors is the promotion of teaching experiences to students.

Teaching related activities are well shaped to provide the wanting and needing to learn ripples that will generate a high level of motivation and self awareness of learning in students.

From the basis of a course designed following an active learning scheme, it is simple to introduce small changes allowing teaching opportunities to take place explicitly.

The analysis of quantitative figures obtained from students marks and qualitative data obtained by questionnaires, are coherent with the expected results. The presented scheme clearly improves motivation and promotes students to be conscious of being learning.

There is one more indicator not still implemented to analyze the impact of course design concerning professional skills demanded by audiovisual industry. A set of contacts have been done with selected professionals actually enrolled in several TV and video production facilities. They will be asked about their opinion concerning the relevance of the skills obtained by students related with real industry needs of the video engineer position.

ACKNOWLEDGMENT

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Session 08C Area 2: Design Experiences - Subject methodologies in design

Design of an Introductory Networking subject in advance of the European Higher Education Area: Challenges, experiences and open issues

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Integrating People and Technology By Design: Design-First Instruction for Introductory Students in Information Technology

Carroll, John M.; Rosson, Mary Beth
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Integrating the Design Thinking into the UCD's methodology

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Toy Design Experience: Improving Student's Motivation and Results in a Final Year Subject

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Design of an Introductory Networking subject in advance of the European Higher Education Area: Challenges, experiences and open issues

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Abstract—**The field of Computer Networks has evolved quickly during the last years. In this paper we consider different aspects of those changes that condition the design of a subject in Networking; specifically, we discuss social, technological and economic aspects. Additionally, the changes proposed in the University studies for the European Higher Education Area condition the design of any current subject. Altogether, these changes condition the design and implementation of a subject on Computer Networks.**

Considering the presented changes we sketch the design of an introductory subject on Computer Networking. The subject is part of a pre-Bologna course, but is designed with the transition on mind. On the paper, we sketch the implementation of the course, designed to simplify the transition to conform the recommendations of the European Higher Education Area. We detail what contents were part of the theoretical or lab sessions, and how we managed to make most lab sessions with mid-class real hardware, introducing relatively complex concepts such as Quality of Service.

Keywords-computer networks; revolution; Bologna process; course design; lab exercises;

I. INTRODUCTION (HEADING 1)

Computer Networks are in a constant evolution. We consider that such evolution during the last decade is not only technical, but also comprises social and economical aspects. These are aspects that should altogether determine the composition of a Computer Networks subject.

The changes in the Computer Networks field themselves are accompanied with a regulatory change in the Education System in Europe. The Bologna process pretends to unify the higher education in Europe, making programs in Universities from different countries compatible with each other. Such change requires a rethinking of each course aspect.

We have considered such the design of an introductory course in Computer Networks before the change to the Bologna requirements, to provide for a smooth transition once a Bologna "grade" course has to be implemented. We describe the course design and how some of our lab courses aim to teach the most interesting and applicable capabilities of networking devices, using friendly exercises.

The main contributions of this paper are:

- A study of the evolution of the area of Computer Networks, focused on how recent changes affect the organization of an introductory University course.
- A rationale about the design of such introductory course on Computer Networks, including concerns about the division of theoretical vs. laboratory sessions, studying outdated technology or not, using simulation tools or real hardware, etc.
- A presentation of some lab sessions, intended to teach advanced concepts (such as QoS capabilities) using affordable mid-range real hardware and multimedia tools.

Specifically, note that this paper is not about converting a Computer Network subject to the requirements of the Bologna process, although we will refer to them in Section III.

The organization of the paper is as follows. Section II studies the changes in the field of Computer Networks during the last decade. Section III considers the changes required by the Bologna process, specifically in what concerns to our country. Section IV presents a rationale of our course design and the contents covered, including an example of our laboratory sessions. Section V presents our experience with such organization and pending issues. Finally, Section VI concludes the paper.

II. REVOLUTION IN EDUCATION ON COMPUTER NETWORKS

The field of computer networks has evolved quickly in the last years. We will focus in the evolution during the last decade (1999-2009, at the time of writing). Such a timescale is sufficiently small to consider that any field with fundamental changes has suffered a `revolution´.

We identify below the three main aspects of Computer Networks that, in our opinion, have suffered a significant evolution during the last ten years. We will first focus on the social aspects: computer networks have become a commodity nowadays, while access to them was uncommon ten years ago. Next, we will study the technical aspects, arguing how the performance evolution (not only in network speed, but with many new capabilities) has introduced new features and outdated others. Finally, we will discuss the economical aspect that limits the implementation of a certain lab exercises. Given the cost reduction of network equipments, new laboratory exercises can be considered with only a limited budget.

Considering the revolution occurred, based on the following three pillars, we believe that many aspects of any subject on Computer Networks should be reconsidered.

A. Ubiquity of Computer Networks – Social aspects

Ten years ago, the access to Computer Networks was not widely extended, and broadband access was in its earlier stage. Specifically in the case of Spain, in 1999 less than 8% of the population had access to Internet, and there were less than 4000 ADSL broadband accesses [1]. Additionally, many computer equipments were not equipped with networking technology (such as a modem or a LAN card). Therefore, most students had no previous knowledge of Computing Networks, not even from the user's perspective.

Nowadays, thanks to the globalization of Internet as a communication channel, students are familiar with both network-based applications and network management. According to the Spanish regulatory organism [2], there are almost 9.5 millions of broadband accesses, with an overall population of 46 million people. While Spain has been traditionally delayed in the penetration of Internet access, these figures are representative of the radical change. Similar figures can be found for other countries.

Of course, these data differ from one country to another. Spain is in an average position in the European Union. In the United States, studies from the U.S. Census Bureau show that the percent of homes with Internet access rose from 26.2% in 1998 to 61.7% in 2007. In 2007, the most recent year with Census data, 50.8% of the householders had broadband access, and 10.7% had dial-up connections [3].

All of our students are nowadays familiar with email, web and distributed applications. Specifically, they are also familiar with the problems of multimedia applications, such as VoIP, videoconference systems, or real-time gaming. These services require special QoS capabilities from the network and suffer when multiple applications make use of the network simultaneously. Regarding network management, surveys carried at the beginning of the course report that about 80% of the students could deploy a local area network, wired or wireless, although they could miss the internal details. For example, they were used to configure NAT on their networks for P2P systems, but most of them did not know how such protocol worked internally.

B. Evolution of Networking Equipment – Technical aspects

Ten years ago contention-based Ethernet or Fast-Ethernet hardware was the norm. Nowadays students are used to low-cost switched gigabit networks and ubiquitous flexible wireless accesses. But the evolution of the technology does not come only from the network speed. The Ethernet standard (802.3, [4]) has undergone multiple revisions increasing its performance and functionality.

Contention-based hardware (CSMA/CD Ethernet hubs) was common ten years ago. Nowadays it has been completely replaced by switches (following the 802.3x standard) that do not present collision problems. Apart from the performance benefit, this makes the Medium Access Control mechanism less important, since now the media is no longer shared. However, the Medium Access Control problem still plays a significant role in wireless networks, were it is impossible to provide a switched mechanism.

Besides the advance in contention management, multiple technologies have been developed and integrated to base and mid-range network products. Among them, we can cite the following:

- Optical links, providing more reliable links between network devices with a high speed and a low error rate.
- Virtual LANs (VLANs, 802.1Q), that allow for multiple users from separate networks to share the same physical network switch without interfering or even noticing each other.
- Traffic prioritization for multimedia applications (802.1P). Such prioritization implements a classification of the traffic (which packets should be prioritized, and which not) and a segregation among multiple hardware queues in the network devices. Different priority policies are assigned to each queue so the most important traffic is cursed first, and it does not suffer from network contention and variable delays.
- Link aggregation (802.3ad), that allows increasing the effective bandwidth between two devices by grouping together two or more physical links and sending traffic using all of them.

All of these technologies are present in today's equipments, and will likely be in future products. Besides, simplified management using web interfaces hides the complexity of the internal design and the requirement to learn commands specific to a single device or vendor.

Of course, we are not the only ones to consider that networking advances should affect the courses. Let us consider the case of Cisco. Cisco is one of the main manufacturers of networking equipments. It also provides certifications [5] about networking, using their own hardware for the examinations. There are different levels of certification, with different contents on each level. The base level has been traditionally the CCNA examination (Cisco Certified Network Associate, [6]). However, in the last years the evolution in computer networks has increased the contents in that examination. Considering the increased difficulties of the additional contents, the lowest level has been divided in two, the CCEnt (Cisco Certified Entry Networking Technician, [7]) and the CCNA levels, with the first one covering the simplest contents.

Finally, this technical evolution has outdated many technologies that were important ten years ago. The list is huge, and includes technologies at different levels, for example: Access to modems using RS-232 serial cables and Hayes commands; network technologies such as Token Ring for LAN or X.25 for WAN; or network protocols such as Novel Netware (IPX/SPX). In our opinion, the inclusion of such outdated technologies in a Computer Networks course should be avoided, unless they have some historical or educational interest.

C. Networking Equipment Cost – Economic aspects

Despite the increases in performance and capabilities presented in the previous section, the cost of network equipments has been constantly decreasing during the last decade, similarly to what happened with most types of computer equipments.

As presented in section *B*, a decade ago a medium-range LAN equipment could be a contention-based hub with some basic management capabilities. A single of those hubs could cost more than 3000€, according to our University IT stuff.

Nowadays, networking systems are much cheaper and more flexible. This allows for flexible mid-range devices to be acquired with a limited budget. In our case, we acquired five switches 3Com Baseline 2916-SFP [8] with optical transmitter modules for less than 5,000€ in 2008. These equipments are suitable for multiple lab sessions, since they have interesting properties such as web-based management, VLAN support, configurable QoS queues, link aggregation, etc.

Fig. 1 shows the basic relations between these three areas. We believe that all the three areas are somehow related with each other. Social aspects are driven by the decrease in the cost of networking products and the increased performance and capabilities. The economic aspects are driven by the advance in technology and the increased market derived by the augmented usage. Finally, technological evolution is driven by the social demand and the market requirements. Altogether, these three aspects should modify the contents of a Computer Network course.

III. THE CHANGES IN THE BOLOGNA PROCESS

The Bologna process intends to provide a uniform framework for University studies across the different countries in the European Union. The current course is currently given in the Spanish "Superior Engineering", equivalent to a Bachelor + Master (a 5-years degree including specialization). However, the Bologna process aims to provide a uniform framework across Europe, similar to the American style, with 3 or 4-years generic "grades" and 1 or 2-years specific "masters".

When designing the subject, we considered that, while the course is still part of a "Superior Engineering" degree, we should focus on the *applied* aspects of the subject, especially considering the changes listed in Section II. Therefore, we insisted on the *useful* aspects (such as configuring network devices, QoS or VLANs) and gave less importance to other aspects that have been outdated by the technology (such as CSMA/CD in contention-based Ethernet networks) or are too specific (such as network dimensioning, which is left for further subjects). Such design aims to simplify the transition to a *less specific* grade course.

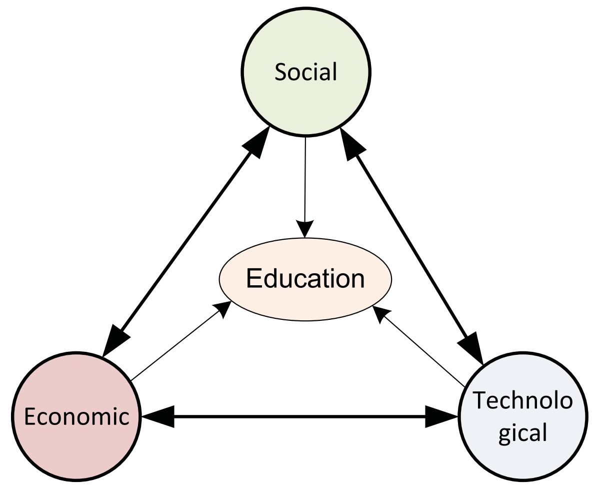


Figure 1. Interaction of the different aspects of the Revolution in Computer Networks that affect Education

Finally, the Bologna system also introduces the explicit idea of competences, divided into specific and transversal competences. While this course, prior to the establishment of the new system, does not need to consider them, we made sure that the proposed model would fit correctly. The core competences are clear, dependant on the course contents. Besides, core competences should be defined concurrently with other courses in the same group. The proposed model, which will be described next, will cover some transversal competences which are commonly discussed in our University: Some lab sessions require the cooperation between the students, exercising the team work; the use of a large amount of proposed problems deals with the autonomous work of the student and his planning of the work. While sketched, all of these competences are left for a future implementation of a grade course.

IV. COURSE DESIGN

In this section we will detail how we have selected the contents of our course, considering the revolution presented in Section II. We present a rationale of different design alternatives. Later, we detail will two advanced lab exercises that show how we exploit some of the switches capabilities: VLAN deployment and a videoconference system with QoS guarantees.

A. Background

The imparted course is part of the "Engineer in Computer Science" degree in the University of Cantabria. It is imparted in the third academic course, out of a total of 5 years in the degree. As observed, current Engineering degrees in Spain are equivalent to a BS & MS in most other countries.

The degree in the University of Cantabria is relatively new; it started in 2005 before any Bologna changes were taken into effect. However, the first time the course was imparted was in 2007, and the European Higher Education Area requirements were already a concern for any course design.

Therefore, the authors considered from the first point the possibility of providing a smooth transition to a Bologna Grade course.

B. *Theory vs. laboratory sessions*

The course contained as many hours of theory lectures as laboratory sessions. There are two basic approaches:

- Use the laboratory sessions to verify experimentally the theory introduced previously in the class, or
- Use the laboratory sessions to introduce complementary contents that are not necessarily studied in the class.

We decided that we should not restrict to the first case if some contents are more suited for the laboratory rather than the class. This allows us to cover a broader content in the course, since the laboratory exercises are complementary to the class lessons.

C. *Bleeding-edge vs. outdated technologies*

While many technologies build on previous standards, in many cases it is useless to teach them. We believe that this occurs when the following circumstances concur:

- The technology is no longer in the Market (so it is never employed in new installations or its products can not be bought).
- The technology does not have a significant installed base that still requires maintenance and management. This is more difficult to know since it requires a deep knowledge on the status of the market and how different companies have adopted new technologies.
- The technology is not part of a subsequent technology. For example, ISDN lines are still in the market, but their penetration is really low and they have been surpassed by other technologies, such as ADSL Internet accesses. However, ISDN switching technologies constitute the base for existent second-generation mobile networks, so it makes sense to know the former before studying the latter.

The first point is clear; for example, it is impossible to find Token Ring products in the Market nowadays. The second point is more difficult to check. In the example of Token Ring products, we could still find some companies maintaining old networks based on this technology. However, a quick search on the Internet (if no other resource is available) will show that such cases are really minor, so they do not justify the study of the technology.

Finally, the third point is the more complex to determine. Despite a given technology can be out of the market (such as Token Ring), its basic mechanisms can be worth studying. For example, the token passing mechanism in Token Ring prevents the problems of collisions when accessing a shared medium. Then, specific parts of a technology can be presented in detail, without the requirement to know the complete system.

In a case such the last one (outdated technology with interesting properties) our approach was the following: First, make a generic study of the possible implementations (in this example, medium access mechanism). Then, discuss the implementation in current technologies.

D. *Course expectations*

An important point for us was the expected knowledgement that a student should get taking our course. Typically, two opposite positions can be considered:

- The student should be able to *invent, design* or *build* a new networking system from scratch, by deeply knowing the involved principles and design parameters.
- The student should know be ready for the day-to-day work, knowing the current technologies in detail and what is currently demanded by the companies.

The first position is the most theoretical one, while the second is the most applied. Both approaches have flaws, since the first case gives no knowledge of the real work, and the second case does not teach the basic concepts in which technology relies.

Of course, we considered that none of these extreme positions gives the best result. In our course, we pretended to mix both approaches. In general, the lab sessions were more focused to the 'real world' approach, while the theoretical lessons would be useful to introduce many of the basic concepts. We further discuss this scheduling in the following subsections.

E. *Simulation vs. real-world practices*

Simulation tools are widely used to teach the main concepts of Computer Networks. Simulation provides multiple benefits, among them:

- The possibility to deploy a network much larger than what is permitted by our real hardware.
- Faster deployment.
- More data are available after the simulation to understand the behavior of the simulated model
- It allows the students to analyze the implementation of a protocol to better understand the behavior of the system.
- Cheap! Most educational simulators are free.

However, simulation also implies some limitations that we cite next:

- Many network simulators are based on traffic models that can differ from what is found in a real application.
- Simulators present a very simple view of the real system, hiding many characteristics that will affect the performance or behavior in the real world.

- The learning cost of the simulation tool could be used to learn some other, more applicable, idea.

Considering the cited limitations and the studied economic aspects, we decided that in general we would try to stitch to the real hardware to give our students a real view of the technology they would find outside of the University. We would restrict to simulation tools when they can be used to better understand a mechanism or protocol without introducing a significant complexity to the students.

Multiple simulation tools exist. We cite some of them next. C.S. McDonald presented his Cnet simulator in [9]. It is an educational tool mainly oriented to studying link level protocols, allowing the users to implement their own protocol. We use this simulation tool in one of our lab sessions. Comnet III [10] is a commercial simulator oriented to network dimensioning. Domínguez Dorado et al. implemented a detailed simulator for MPLS traffic [11]. It can also simulate QoS capabilities. However, MPLS was out of the scope of our course. Goyal et al. propose [12] a graphical simulation tool to evaluate network performance. However, many of their proposed lab sessions are out of the scope of our subject, and others concern outdated technology such as Token Ring. Surma [13] proposes a set of activities to understand the behavior of some network protocols. While such active learning games are excellent to motivate students, we prefer them being able to study the detailed code in a simulation tool such as Cnet. Finally, virtualization is being widely used in many laboratories as a tool for the student to work with one or multiple computers at the same time. While this could be interesting in other fields, it does not fit with our course since, essentially, it removes all of the networking issues that we study in the course.

F. Course schedule

Our introductory course on Computer Networks belongs to the third year of the degree on Computer Science Engineering. It is followed by a subsequent course in the fourth year. These two courses are complementary: Our course focuses on the main principles of networking (data coding, transmission protocols, multiplexing, etc.) and the first two levels of the network hierarchy: physical and Network access. The subsequent course in the fourth year deals with network layers 3 and 4 (TCP/IP).

The course is divided into three sections. First, theoretical lessons are used to present the contents to the students. Second, we provided a wide collection of problems with the final solution, so the students can apply the theoretical contents. Finally, we developed several complementary laboratory sessions, mostly using real hardware, to complement the other areas.

Theoretical lessons are organized in 9 sections. As commented before, we introduce basic networking mechanism and the two lowest architectural levels, based on the organization in [14]:

1. Introduction
2. Protocol architectures, showing both the OSI and the TCP/IP models
3. Data transmission, including aspects about digitalization of analog data (such as audio or video.
4. The physical layer, detailing multiple transmission medium, data codification mechanisms and signal propagation. Also, we introduce the concepts of structured cabling and ISO 11801.
5. Link layer mechanisms, including flow control and error control mechanisms.
6. Multiplexing mechanisms.
7. Circuit and packet switching.
8. Local area networks
9. Wireless networks

Obviously, the last two sections are the most important ones, but they rely on the contents of the previous ones. Each of these sections, except for the Introduction, is accompanied with a set of problems with a final solution provided, so the student can work autonomously. Problem discussion is derived to a forum on the course website.

We designed 9 laboratory sessions, oriented to complement the theoretical ones, 2 hours each:

1. **Ethernet cable fabrication.** The students have to make a cat5e cable with the proper connections, and validate its correctness. Two tools are used for validation: a naïve pin checker (that checks electrical connectivity) and a Fluke cable certifier used in real installations. This device was borrowed from the University IT service, since we could not afford it, and the high expense was not worth for a single session.
2. **Serial cable fabrication** using DB-9 connectors. While this cable has been outdated, it is still in use in many current devices. Also, it introduces the concept of flow control in a simple manner.
3. **Flow control simulation.** We used Cnet [9] for the study of simple stop&wait flow control protocols. The students have to study and understand the performance of the protocols, and modify the existent code to add new functionality, such as introducing negative acknowledgements. We selected a simulation tool for this session since flow control protocols are difficult to study using real hardware.
4. **Introduction to LAN networks.** The students had to set up a wired LAN network using both hubs and switches. Wireshark [15] is used to analyze the traffic in the network and observe, with multiple PCs connected to the same device, the difference between hubs and switches. The hubs had been also donated by the IT staff, retired from our University, and are used in this session to show contention-based access control.

5. **Switch management and fiber links.** We introduce the web-based management interface for the switches, shown in Fig. 2. The students use it to configure the speed and duplex properties of their own links, and configure a larger network using fiber links.

6. **Security aspects.** It introduces the MAC address learning mechanism and MAC filtering mechanisms to provide security in the network.

7. **Virtual LANs (VLANs) and link aggregation.** The idea of virtual LANs is studied by configuring multiple VLANs in their own switches, and configuring a network comprised of multiple switches with several VLANs, using tagging to propagate the VLAN information. Link aggregation is also introduced, as a way to increase the capability of an individual connection by using two parallel links.

8. **Traffic prioritization.** It studies the prioritization of traffic between multiple flows in a single link. This session is shown with more detail later.

9. **Wireless LAN.** 802.11 wireless networks are introduced. Students configure multiple networks in the lab, and study the available throughput on each case (between wired or wireless clients, in the same channel or a different one).

It can be observed that sessions 5 to 8 use the advanced capabilities of the switches discussed in Section 2, while other sessions are more basic. We detail next two interesting sessions that make use of the advanced capabilities of the switches.

G. *Virtual-LAN lab session*

This advanced lab session explores the work in groups. The idea is that the students must build a single network in the laboratory, but comprising different virtual LANs. Each VLAN is seen as a separate LAN for the users connected to it, although all of them use the same network equipments to lower the implementation costs.

Fig. 3 shows an example case. Our desired implementation contains two networks, one for management operations, and another one for the students. The equipments in different networks should not access each other, so the simplest

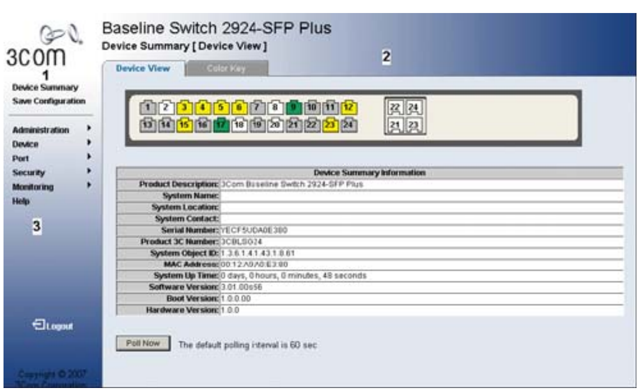


Figure 2. Web-based management intefarce of the laboratory switches.

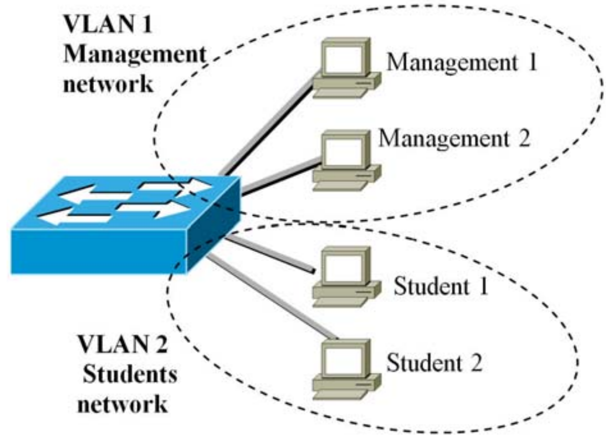


Figure 3. Two VLAN networks in a single switch.

configuration would be to use two physically separated switches. However, a single switch with two VLANs configured, as presented in the figure, gives the same service.

The interesting configuration problem arises when equipments in the same VLAN are connected to different switches. In this case, the connection link between the switches must be configured to transfer VLAN information with each frame. This is a distributed configuration, what forces each group of students to collaborate with the others in the configuration, validation and problem solving phases of the work. Similar problems are faced in the second part of the session, in which multiple links are laid between each pair of switches to aggregate their speeds and provide more performance.

H. *Traffic prioritization lab session*

We will detail now a session of our laboratory that uses multimedia, switch management and group work to study the effect of network congestion and how to solve it with prioritization at OSI level 2. As discussed in Section 2, the effects of congestion are familiar to the students, since it affects multimedia (VoIP, videoconference, video on demand) and network gaming, among others.

We configured a 10 Mbps link between two switches to model a congested WAN access, as presented in Fig. 4. Multiple PCs used FTP to transfer large files (sustained transfer) across the shared link. Simultaneously, the PCs on port 1 of each switch had webcams that would transfer video between each other. We used the VLC player [16] to encode, transfer and receive video at 4.5 Mbps using MPEG-2. This emulates a videoconference system that runs on the same link as the remaining traffic from the FTP transfers.

Without any prioritization, the video would show clear transmission artifacts, as presented in Fig. 5a. The lack of sufficient throughput and variable network delays affect the quality of the transmitted video. The image shows macroblocking and false colors artifacts.

The laboratory switches provide four hardware queues per port. Traffic flows can be inserted to one or another depending on their input port or their priority tags (CoS at layer-2 or ToS

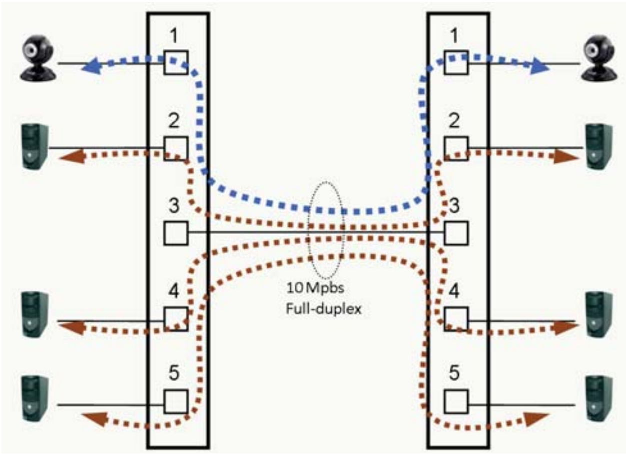


Figure 4. Schema used to obtain congestion in a network link. Both switches are connected trough port 3. The computers on port 1 of each switch make a videoconference enconded with 4.5 Mbps. The other computers transfer files on both senses.

at layer-3). Different hardware queues have different priorities (strict priority or weighted round-robin) when they compete to transmit on the same link, in our case, on the link between ports 3 in both switches. By configuring the video in the strict priority queue and the remaining traffic in one of the remaining ones, the students guarantee that the video transmission does not suffer from the concurrent file transfers on the same link. The result when the proper prioritization mechanisms are employed is presented in Fig. 5b, where the concurrent transmission of 3 files does not affect the video quality.

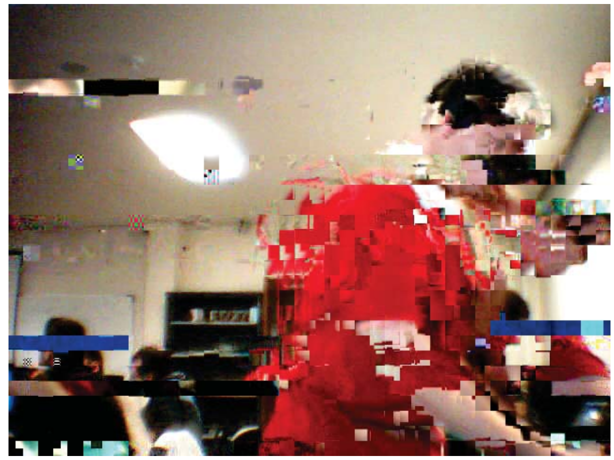
Other approaches study quality of service with a quantitative approach [11]. By contrast, our practical approach is highly qualitative. We believe that this simple and visual approach, with familiar problems (such as video pixelation) that are solved with prioritization, are better suited for the introduction of the problem and associated solutions to the students, leaving detailed studies of the quantitative performance for further courses.

V. Experience and Open Issues

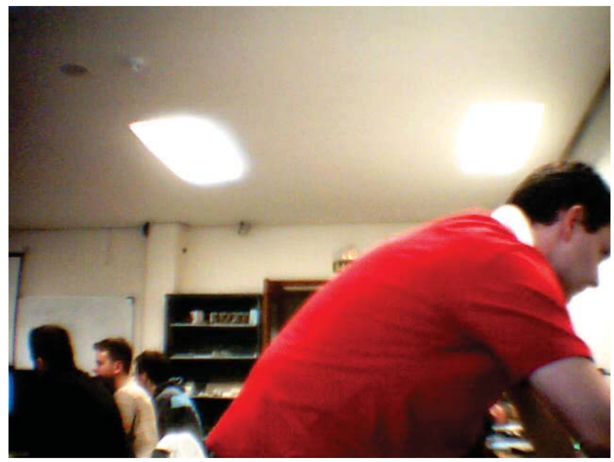
The proposed organization is now running for the second year. We have observed that the students understand the contents presented and can follow the course without major problems.

One of the main issues with the lab sessions is that many of them introduce relatively advanced concepts. Therefore, we have determined two concerns:

1. Special care has to be taken with the synchronization of theory and lab sessions. The start of the lab sessions could be delayed a few weeks until the necessary background has been presented. When the lab sessions refer to contents not yet introduced in the theoretical class, the lab instructions must be accompanied with the necessary contents.
2. It is required for the students to read the instructions before the lab session so they are familiar with the exercise and the involved technology. Otherwise, the 2 hour limit is not enough to finish the proposed exercise. We observed that in many cases the students would omit this step, and would have problems in the session. While we have not done so yet, we are considering the idea of adding a quick test about the instructions at the beginning of each session. Such a test, with a low impact on the final grade, would incite the students to prepare the lab sessions thoroughly.



a) No prioritization mechanism, no QoS



b) With proper prioritization on the shared link

Figure 5. Example of video received when multiple traffic flows share the same link. Case a) shows the result in the default case (without any priorization mechanism) where packet loss is observed in the form picture errors and macroblock patter showing. Case b) shows the result when the port queues are properly configured.

We also noticed that the effort required to prepare the setup of each lab session (prepare switches, cabling, configuring equipments) was relatively high. This is a cost to be paid for the advantage of lab sessions with real hardware.

Our main concern for the future is the adoption of this course to the Bologna requirements once the new 'grade' is working. However, we believe that our practical approach is well-suited for the change.

VI. CONCLUSIONS

We have argued that the evolution in Computer Networks, not only in the technological aspect, must condition the way that corresponding University courses are designed. Specifically in the current context, the technology, economic aspects and students' background allows for relatively advanced contents to be taught without requiring a large effort. We believe that similar discussions should apply to most technological courses.

Based on the previous discussion, we have presented the organization of our course and detailed the laboratory sessions using affordable mid-range hardware. Our experience shows that this approach is affordable for the students and provides better results than using exclusively simulation-only tools.

ACKNOWLEDGMENT

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Integrating People and Technology *By Design*

Design-First Instruction for Introductory Students in Information Technology

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Abstract— **In the design and implementation of interactive systems, teams typically consider and debate multiple perspectives, for instance exploring objects comprising a problem domain, the user population, and current technologies that might be useful. In this paper we report a field trial of our approach to using analysis and design activities as an integrating framework for introducing introductory students to the dependencies among information, people, and technology in information systems development. In this course, students work individually and in teams to 1) analyze structured information; 2) understand relationships implicit in online information; and 3) design technology concepts. We describe the activities we have developed and a preliminary evaluation of student outcomes, including a discussion of the mediating influence of students' technology background.**

Keywords - design-based learning, interdisciplinary education, team projects

I. Introduction

In response to the information explosion in society – and the corresponding need for interactive systems to store, access, manipulate, and present information – the iSchool concept has surfaced as an interdisciplinary paradigm for university education in computer and information science [1]. An *iSchool* is a college, school or other university program concerned with the social, cultural, and technical issues surrounding the design and use of information systems. A defining feature is a focus on *information*: what information is; how it is gathered and used; how it is transformed and stored; and its risks, benefits, and other consequences for a multitude of stakeholders. iSchool researchers seek to understand information in a contextualized fashion, which leads to an interdisciplinary research community; for example our own program integrates computer science, psychology, cognitive science, sociology, business, education, law, geography, and medical informatics. Another focus point is *design*, by which we mean the materialization of information to support human activity, through a sociotechnical process that interleaves theory, sociocultural and psychological studies, and technology innovation and implementation [2].

Shared visions of iSchool education are still evolving. There is not yet a standard curriculum such as exists for computer science or engineering [3]; indeed many iSchools focus primarily on research and graduate studies. Our four-year baccalaureate program combines sociocultural and human-computer analysis with technology fundamentals like databases and networking. Although our undergraduate students are exposed to modern programming languages (e.g., Java), most do not develop strong software skills, limiting their capability for innovative systems design work. In this paper we describe steps we are taking to inject hands-on *design* experience into the program's introductory course, conveying basic analysis and design skills that would provide a solid foundation for more advanced system design courses and projects.

In brief, we enhanced our college's introductory course with design-oriented activities to reinforce the course's general learning objective to introduce an integrative view of information, people, and technology. The enhancements comprise several active learning modules that mix homework assignments with three phases of a semester-long team project. In the balance of the paper we present the motivation for and design of these activities, the results of our initial implementation in two large sections, and the broader implications concerning design as an integrative concept for technology education.

A. Design as an Authentic Integrating Activity

We propose that design can serve as a powerful integrating activity for students who are being introduced to the subtle and complex interacting influences of information, people, and technology in society. Through their design activities, students are led to articulate, confront and resolve tradeoffs, while at the same time experiencing the empowerment and reward that comes from creative work [4].

A particularly attractive aspect of design as an integrating concept is its *authenticity*. iSchools span the information disciplines to comprehensively address issues ranging from image processing to social policy. In this vast spectrum, design is a fulcrum. One cannot talk about information processing, storage and retrieval, information behavior, the use of information in groups, organizations, or in society, or information policy and regulation without making strong and substantive assumptions about the specific ways that information can be presented to and manipulated by people [2].

The information explosion on the web is at once a driving factor for the emergence and refinement of the iSchool vision and a resource for exploratory learning of design concepts and skills. A broad array of public information is available to any web-active user who seeks it, for example social networks, weather updates, stock information, news, sports, along with many others [5]. This web information and services can be used for authentic learning about information systems design

[6]. One defining feature of authentic learning is that students become immersed in real world problem settings, so that the understandings and connections they form are general and reusable in future settings [7] [8] - the web provides ready access to such settings.

Learning by design is authentic due to the open-ended yet goal-directed process that designers follow. Design is not puzzle solving; there is never a "right" answer [9]. But clearly design is motivated by goals; these goals are translated into more and more concrete specifications as they are better understood and mapped to possible solutions [4]. The authenticity of learning by design can be enhanced even more if it takes place in a team setting, with peers brainstorming and negotiating to construct shared design ideas. A shared process such as this allows students to experience the collaboration, tool manipulation, domain-specific goals and heuristics, problem solving, and reflection-in-action typical of professional work [10] [11].

B. *Leveraging the Web for Learning by Design*

The phrase "Web 2.0" has emerged as a label for web technologies that allow users to take an increasingly active role in their use of online information and services [12]. In other work, we have been investigating the opportunities and challenges in making these web technologies more useful and usable to end users [5,13]. For example, we are studying modern university students, young adults we call "web-active end users" – they engage in many ways and for may purposes with web information and services (e.g., media sharing, online news and discussions, social networking), but they have no programming background or skills to apply to these activities.

In addition to providing information in many forms, the internet hosts a rich selection of tools to visualize and make sense of information. Figure 1 shows a typical example from Digg Labs, the BigSpy visualization of , a visualization using timing, color, font size and numeric annotations to convey real-time newsreading patterns. Our studies of web-active end users indicate that they already understand and expect to work with dynamic web services like these. Thus we decided see if we can use web information systems of this sort to engage students' curiosity and motivate a deeper understanding of online information and its design implications.

Figure 1. Screenshot from digglabs.com "BigSpy" visualization.

We organized students' exploration of web information system designs into three phases. First we emphasized the *structure* of the underlying information, so that students would begin to think of a stream of real-time web data as comprised of an organized sequence of information elements. Next we shifted attention to the *uses* of information – how to think about users' needs and preferences, with a focus on information analysis as a pervasive human activity. Third, we introduced simple technologies for *programming* with online information, leveraging emerging tools for web mashups [5]. We turn now to a more detailed presentation of the learning activities and student experiences.

II. COURSE ACTIVITIES

Historically, our introductory course introduces students to three facets of information-intensive systems: information, people, and technology. Table I summarizes the overall plan for the course, showing how the general concepts and concerns of information systems design recur across facets (e.g., layers, sociotechnical analysis, information organization); at the same time different elements within this pool of constructs come into focus within different facets (e.g., data concepts are primary in the first facet and usage concepts in the second). This general organization formed a background for the three activities focused on web information systems: we integrated the data analysis module into the first facet, information usage into the second, and web programming into the third.

TABLE I. OVERVIEW OF THREE-PHASE COURSE PLAN

1) INFORMATION: Understanding sources, types, roles, and management of information in digital society • Data basics: What is data, how do we store it? • Spreadsheets and databases: How do we create efficient and reusable information repositories? • Information sources: the Web, input and output, multimedia. • Information applications: What makes information relevant, how is it used to address problems, issues, or needs. • The future: Where are we headed?
2) PEOPLE AND ORGANIZATIONS: Understanding the mutual influences of people, organizations, society on information technologies • Human-computer interaction: Analyzing and designing information systems to respond to human needs and preferences. • Situated use: Representing and studying both explicit and tacit aspects of a usage context. • Groups and organizations: How the roles and relationships of groups and organizations affect information systems • Socio-technical analysis: interleaved evolution and adaptation of social systems and the technology in use. • The digital society: Use and design of IT in our world
3) TECHNOLOGY: Understanding the infrastructures, protocols, and tools for accessing and manipulating information • The Internet and Web: History, evolution, how it works. • Networks: Technology, protocols, media, methodologies for creating, maintaining, and debugging networks. • Layered systems development: Introducing the basic architecture of information-intensive systems analysis and design. • Quality attributes: Usability, reliability, maintainability, reusability • Emerging technologies: Artificial intelligence, multimedia, ubiquitous computing

Each module consists of an individual homework assignment and a phase of a semester-long team project. For example, the first module was focused on information, and students worked on a structured information analysis of a simple domain (an animal shelter) while their group brainstormed, identified, and analyzed the information domain that would be the focus for their semester project. We hoped that in their individual work students would gain basic concepts and skills, and through collaborations withteam members they would apply these skills to projects that are larger in scope. summarizes specific objectives for each module and the following sections describe each in more detail. A complete set of course materials can be obtained from the first author, but we provide a summary description here.

A. Module 1: Analyzing Structured Information

In the class sessions associated with first module, students were introduced to simple abstractions for thinking about the structure of online information. For instance, we visited the BigSpy website illustrated in Figure 1 and discussed the information attributes that might be used to create such a visualization. We talked about the use of tags for describing such structures, and visited RSS news feeds in browsers, using the "View Source" option to see the specialized tag set used to describe RSS data streams. We also talked about databases in general terms, using simple SQL expressions to show how logical expressions can be used to retrieve specific records or fields in a structured data set. In the individual homework, students analyzed a familiar object (the class itself) using a simple data tree that they then converted to a set of tags, illustrating the tags through some sample markup.

The Phase I project assignment was for each team brainstorm, identify and analyze an information domain that would form the basis of their semester project; they were encouraged to work with information domains for which members already were familiar with or had interest in researching. They produced a concept map (using the collaborative Mindmeister tool, mindmeister.com), investigated activities and information objects making up the domain, and defined and exemplified a set of XML tags for a central information object in the domain. Topics were diverse, for example: coaching college football, getting a record deal, using a university library, military communication, and online shopping. The major challenge during this phase was scoping the topic enough to guide their analysis of information used in the domain, and in particular to select an information object for detailed analysis. Examples of objects that teams analyzed and represented using XML tags included electronic patient records, schedules of varying sorts, a security audit, product inventory, and contracts of varying sorts.

B. Module 2: Visualizing Social and Organization Structures

In the second module, course content shifted to the human side of information technology in use. This included a basic introduction to human-computer interaction concerns and guidelines, as well as central concepts from collaborative work and socio-technical studies of organizations. A central issue was the many consequences that technology can have in different usage contexts, where context is defined and analyzed at multiple levels (individual, informal collaborations, project team, organization).

In the individual assignment, students were introduced to the Motion Chart tool that is part of Google Docs spreadsheets (this tool is a simple variant of the GapMinder tool introduced and popularized by Hans Rosling for analysis of world health data). Using Motion Chart, students can create simple time-based animations of data sets entered in a prescribed spreadsheet format. The spreadsheets must conform to an expected structure with respect to year information and other columns, but other than this the tool can visualize anything that includes numeric data as an "outcome variable" associated with a mix of either categorical or numeric "independent variables". In the tool the outcome variables are graphed and can be viewed as they change over time as a function of the other specified variables.

The data set provided to students was a randomized list of hypothetical company records. Each record had data about complaints to management for a given year, and the companies varied according to their adoption of computer-mediated communication tools (CMC), their size, and their industry orientation. Students were told to create a visualization that might explain the variation in complaints submitted. In this case there was an obvious correct answer, where companies that were smaller (thus benefiting more from the social distancing expected from CMC) and more competitive (thus provoking more complaints in general) were influenced to a greater extent by increases in CMC. Once they worked out how to use the tool, students had little trouble discovering and explaining this relationship based on our class discussions. Figure 2 contains a sample visualization shown at two different points in time.

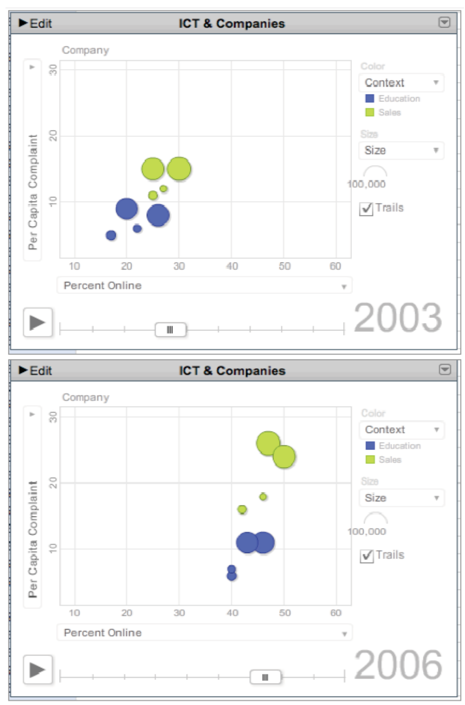

Figure 2. A sample Google Motion Chart at two points in time

In this module, the teams were assigned to continue their work from Phase I, but shifting attention to the stakeholders and potential uses of the information they had analyzed earlier, with particular focus on the information object they had investigated and represented in more detail. The teams produced a table of usage situations with associated stakeholders, a stakeholder diagram that illustrated concerns associated with different levels of analysis, and persons (user descriptions) that conveyed typical characteristics of individuals drawn from across the proposed usage situations. For example, one team working in the problem domain of movie production considered use situations like researching actors and marketing movies; stakeholders that included cast members, director, production crew, unions, movie theaters; and person variables like personality, technology experience, and gender.

C. *Module 3: Designing Information Technology Solutions*

The final module was focused on the technology used in information systems. In class we discussed the technology from a systems perspective (e.g., network architectures with associated performance and security implications) as well as an end-user perspective (e.g., typical and more emerging input and output techniques, including multi-touch displays, augmented and virtual reality, and ubiquitous computing). We also discussed simple "programming" concepts, focusing on end-user techniques like faceted search, keyboard macros and web mashups.

The individual assignment was to experiment with an example mashup that had been created in advance. We used the Yahoo! Pipes tool (pipes.yahoo.com), as our ongoing research has indicated that its visual programming language is reasonably accessible to nonprogrammers [13] and it is robust enough for experimentation by unsophisticated users. The sample mashup was chosen as one that might be attractive to college undergraduates (college football enthusiasm was at its height then), and involved selection from and integration of two sports feeds. Students were required to explain how the mashup is working, and to carry out two different experiments to enrich its output – in one they simply changed the selection criteria, and in the other they integrated a third image feed. Figure 3 shows an example of the second experiment.

The team assignment in this module required production of both a written report and a final design deliverable in the form of a concept video. Because the students had not been taught programming skills, we instead taught them to use a range of techniques for mocking up design concepts (e.g., paper prototypes, animation of simulated workstation screens). They used these techniques to illustrate their design concepts that were then conveyed as part of a video. The video enacted one or more task situations associated with their information domain, with the appropriate mockups (e.g., a data visualization) inserted and "used" at relevant points. For instance, a team working on a library concept videotapes several cases where a student used a mobile phone mock-up (build with paper overlays) to access useful information that would help him locate and retrieve library resources while in the library. Sample videos can be obtained on request from the first author.

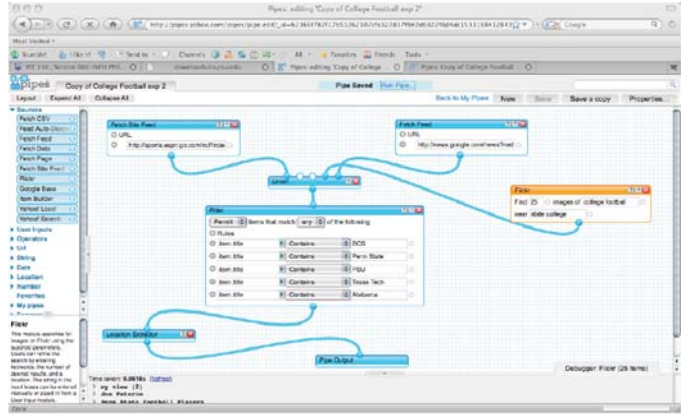

Figure 3. Sample output from Yahoo Pipes assignment.

TABLE II. SUMMARY RESULTS FOR HOMEWORKS AND TEAM PROJECTS

Individual Homework	**Phases of Team Project**
Information Structure Average score: 10.4 Max 12, range 3-12	*Information Domain Analysis* Average score: 23.8 Max 25, range 20-25
Visualizing Social Structures Average score: 14.2 Max 15, range 2-15	*Stakeholder and Usage Analysis* Average score: 33.0 Max 35, range 24-35
Web Information Mashup Average score: 17.4 Max 18, range 6-18	*Design Concepts Video* Average score: 33.0 Max 35, range 27-35

III. CLASSROOM EXPERIENCES AND OUTCOMES

The field trial of the three-phase curriculum took place in two large-enrollment sections of the course that was taught in Fall 2008 (one section had 137 students, the other had 126). Although the activities were assigned to all students, only data from students who gave informed consent to be research participants is summarized in this paper. Across the two sections, 158 students gave such consent, but because of missing data, some of the summary values reported here are based on a partial data set. Of the 143 students who indicated their major program of study, 91 (58%) were pursuing a major in this college; other students had not yet decided on major (13%) or were enrolled in some other program (e.g., Finance, Telecommunications, Psychology, Supply Chain). Because this introductory course can be used to meet a university-wide requirement for social science education, it tends to attract quite a diverse population of students. Among the 144 students who reported their gender, 22% were female and 78% male.

With respect to the design-focused learning activities, performance was generally high, as summarized in Table II. Although some students failed to submit one or more individual assignments, those who did tended to meet expectations; summing across all potential homework points (45), the average was 39.6 (88%). Performance on the team assignments was even stronger: out of 95 possible points, the average was 89.9 (95%). The high scores for team assignments are typical for classes of this sort, as evaluation of shared deliverables primarily focuses on whether the team followed the specification. Not surprisingly, both individual performance and team performance were related to students' final course grades (r=.79 and r=.49 respectively), with participation and quiz grades also playing important roles (r=.78 and r=.74 respectively. The overall class average was 87.8%, ranging 55.6% to 99.2%.

IV. Perceived Self-Efficacy

In addition to the grade-related outcomes, we collected 33 self-efficacy ratings before the course began, with repeated assessment at the end of class. Self-efficacy refers to one's belief about specific capacities in a proscribed context or situation (e.g., a task; see Bandura [14]); items assessing self-efficacy are often used as surrogates for achievement as they tend to be highly correlated with other outcome measures. Our items were designed to assess capacities related to skills taught in this particular class; students responded on a scale from 1 to 7, where 1=Strongly Disagree and 7=Strongly Agree. The majority (24) of the items had been in use for several years by other instructors to assess learning objectives for this course. Nine items were developed for this project and focused on more specific capacities related to analyzing the structure of information and working with web information. A complete copy of the self-efficacy items can be obtained from the author.

TABLE III. Sample Self-Efficacy Items from Four Subscales

Identification with the baccalaureate program (Program) • In the course of applying for an internship, I could describe at least three distinctive features of an IST education to the interviewer. • Despite my limited experience, I can make a convincing argument that problem-based learning is the best way to get a degree in IST.
Computer and Information Technology (Inf Tech) • If I were writing a show called "Computer World," I could create dialogue for characters such as data, memory, central processing unit, and motherboard. • In the checkout line at Wal-Mart a woman asks, "Why don't they just use a cash register? Why do they need bar codes?" I could explain barcodes to her and tell her how they reduce costs.
Web 2.0 Applications(Web 2.0) • If I were demonstrating the use of Flickr to my mother, I could describe several attributes of photos that it tracks to calculate social networks. • If my boss asked me to "mashup" the highlights from a presidential campaign, I could locate, combine, and visualize several online information feeds.
Structured Data Models (Data Model) • Although I am not a sales professional, I could predict 5-10 database fields that would be needed as part of an online grocery store. • Despite my limited experience with computer programming languages, I could use a mark-up language like XML to describe the people in my family tree

Rather than examine self-efficacy as a single construct, we used data reduction techniques to develop several subscales that assessed different aspects of students' beliefs about their capacities at the start and end of the course. Factor analysis of self-efficacy data from earlier instances of this course had revealed two stable factors, one interpretable as ability to appreciate and succeed at the baccalaureate *Program*, and another capturing general skills in *Information Technology*. Factor analysis of the new items developed suggested the presence of two additional factors that we identified as *Web 2.0* and skill in analyzing or building *Data Models*.

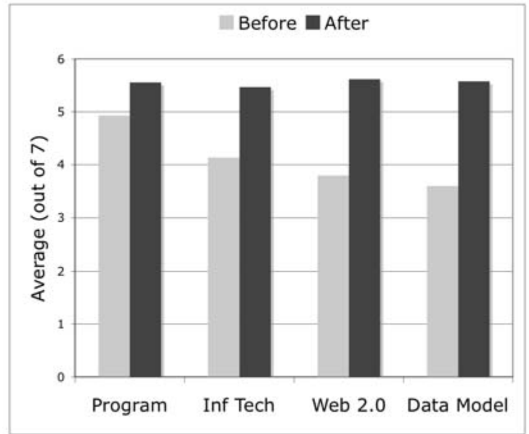

Figure 4. Self-efficacy scores at start and end of course.

To generate the indices we aggregated items loading most strongly on each of the four factors; the four constructs with examples of items loading strongly on each appear in Table III. Not surprisingly, average self-efficacy scores for these four capacities varied at the start of the semester, ranging from a mean of 4.94 for Program, 4.14 for Inf Tech, 3.80 for Web 2.0, and 3.60 for Data Models (F[1,142]=51.66, p<.0001). That is, these introductory students began their course with relatively more confidence about succeeding in the baccalaureate program, but relatively less confidence that they could design web systems or construct data models.

After creating the four indices and ensuring their reliability, we constructed isomorphic indices from the post-course survey. The resulting contrast of self-efficacy ratings before and after taking the course are graphed in Figure 4. As the graph suggests, students reported higher self-efficacy for all four indices after the class was over (t(106)=5.61 for Program; t(107)=9.73 for Inf Tech; t(106)=12.54 for Web 2.0; and t(106)=13.68 for Data Model; all significant at p<.0001).

We were particularly pleased to see the relatively greater self-efficacy increases for Web 2.0 and Data Model. At the start of the course, these ratings were lower than those for Program and Inf Tech (F(3,426)=58.72, p<.0001). At the end however, the ratings for all four subscales were about the same, suggesting that the perceived gains for specific capacities relating to Web 2.0 and Data Model were more substantial than the other two subscales. A one-way ANOVA that analyzed self-efficacy *gains* confirmed that this was true (F(3,318)=41.53, p<.0001). These survey results are promising, in that they suggest that students felt most impact in the specific capacities we had targeted with the new learning activities.

Because the student population in this class was quite diverse, and because a general goal for this course is to provide a broad introduction to information, people, and technology, we conducted an exploratory analysis of the possible relationship between students' starting background and their success in the class. We had included four expertise-related scales in the background survey: experience rated on 5-point scales for traditional programming languages, web authoring, working with digital media, and use of wiki/blogs. These four items were correlated, with an inter-item reliability of .71, so we created a single Tech Expert index by averaging the four items. The resulting index ranged from 1.0 to 5.0, with an average of 2.22.

Interestingly, students' technology background seemed to be unrelated to their overall performance in this introductory course: the correlation of Tech Expert with final course grade was -0.02, ns. It may be that the learning activities – including significant emphasis on team activities that might include peers with greater expertise – were enough to erase any advantage the more expert students had at the start. Not surprisingly, Tech Expert was closely related to all aspects of initial self-efficacy ($r=.28$ for Program; $r=.49$ for Inf Tech; $r=.52$ for Web 2.0; $r=.60$ for Data Model; all significant at $p<.001$). Informal comments from students after the syllabus was previewed on the first day reinforced this relationship, with many of the less sophisticated students voicing concerns about their chances of success in the course.

When we explored the relationship of students' technology background with *gains* in self-efficacy we found a striking pattern. For simplicity, we grouped students into low and Tech Expert groups using a median split. We found that although Low Tech Expert students reported lower self-efficacy for every subscale at the start of class, these differences were gone by the end of the semester. In other words, all students increased in self-efficacy, but those who began with the *least* technology background had the greatest gains. The differential gains for these less expert students were largest for the Web 2.0 and Data Model subscales ($F(3,103)= 2.82$, $p<.05$), again emphasizing their gains in knowledge and skills that are most "technical" and specific to this course. Figure 5 graphs these results emphasizing the relatively greater semester gains for Lo Tech Expert students in these two self-perception areas.

Although we hesitate to place too much emphasis on the results of these exploratory analyses, one interpretation of this pattern of results is that the three modules (and indeed the course in general) were of most use to students who had relatively little background with programming or online tools. This is a positive outcome for the more inexperienced students, but raises a question about the learning benefits of the new activities for students who arrive with a strong technical background. This issue of course is one that faces any educator who offers an introductory course to a diverse student population that includes many variations in prior knowledge and skills.

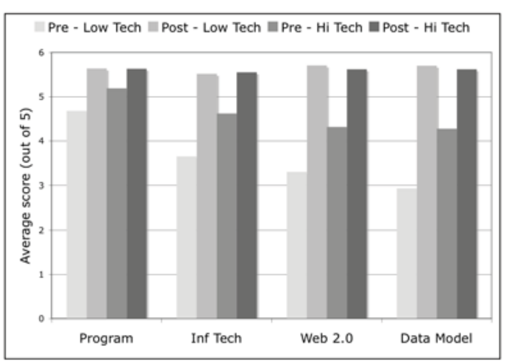

Figure 5. Self-efficacy scores at start and end of course.

At the end of the post-course survey, we asked students to reflect on whether the emphasis on design was useful to them. 95 students answered this question, and of these, most (83%) agreed that the emphasis on design was useful; the remaining students were either neutral (8.5%) or negative (8.5%). The rationale for these opinions was as one would expect – many of the positive responses cited the integrative effects of design thinking, or that it leads you to view problems from multiple perspectives. Of course these reflections were quite consistent with the rationale provided along the way as the project and homework activities were introduced, so to some extent the students are likely just "parroting back" what their instructor has told them. Some students (24%) made more specific comments, for example saying taking an information systems design perspective made them feel more connected to the real world, or that it made them feel better prepared them to work with real world problems. The neutral or negative comments tended to have less explanation, but seemed to come from students who felt they never "got it", or who complained that they already knew how to do everything presented in the class.

V. Discussion

We have described a design-based approach to promoting an interdisciplinary view of computer and information science, with an emphasis on introductory students who are first encountering and considering the challenges of the field. We experimented with several learning activities that focused first on data structure, second on discovery of implicit social and organizational relationships, and finally on innovative design concepts. We found that students were able to complete the activities, and that perceived self-efficacy for data modeling and web 2.0 application design increased. Finally, we found that these benefits were most apparent for the students with least technology background on entering the course.

While clearly still in its early stages, this educational development effort makes several contributions. At a practical level, we have developed and evaluated several specific learning activities suitable for an introductory class in the interdisciplinary information science programs that are emerging as part of the iSchool trend; these activities as well as our assessment instruments can be obtained by request to the first author. More generally, we have taken a step toward understanding whether and how design analysis and thinking can help novice information professionals learn to consider and integrate a range of different perspectives in solving information technology problems. Finally, we have documented the impacts of technology background, raising questions as to whether the activities should include more advanced learning options.

Taking a larger perspective, an introductory class such as we have described fits well within broader discussion of computer and information science curricula. For instance, there has been an ongoing discussion about whether and how to introduce more of a design (versus programming) emphasis early in an information technology curriculum. The materials and activities presented here offer one mechanism for introducing a more pronounced design emphasis prior to requiring a solid foundation in software development skills.

Although the activities prototyped in this class were successful, there is much to do. The individual and team assignments overlapped in broad terms, but our long-term pedagogical goal is to connect them more tightly. For example, we hope to decompose the work needed for the team project into individual components that each team member "practices" on the way to collaborating with his or her team. If we can do this, we may be able to reduce the tendency to distribute group work among people according to their starting levels of expertise – which of course counters much of the cooperative learning that we as educators hope to promote in group activities. We have found that the final team assignment – in which design concepts are mocked up in a video – is engaging, but we need more convenient and accessible tools for prototyping and video construction, so that the final design concepts can be expressed in a more realistic fashion. The more authentic the design outcomes can be, the better prepared the students will be for tackling interdisciplinary projects in the real world.

ACKNOWLEDGMENT

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Integrating the Design Thinking into the UCD's methodology

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Abstract—**In this paper we describe how we have integrated several techniques of the "Design thinking" (DT) into the User Center Design (UCD) methodology in the process of development of project as a learning activity. The experimental activity has been carried out with students of the Human Computer Interaction's subject, corresponding to the 3º course of the School of Computer Science of the University of La Laguna.**

Keywords: Design Thinking, UCD, HCI, elearning

I. Introduction

The Human Computer Interaction is a subject corresponding to the 3º year of the Computer Science Engineering of the University of La Laguna. This subject include the contents relating with usability, accessibility, design for all and User Centered Design (UCD) methodology. Since 2004, we have been using a learning methodology based on projects and collaborative work and the blended learning model supported by Moodle. During the first course, several activities of Computer Support Collaborative Learning (CSCL) has developed [1]. Among these activities, we can highlight the creation of wikis (inter & extra groups) with a clear specification of roles and distribution of tasks. In the successive courses, this work group and based on projects' methodology has continued, changing the type of activities and experiences carried out to the laboratory. So, we have worked since the integration of multi player video games with Moodle, analyzing the motivational factors in learning process [2], to the creation of collaborative conceptual maps to support the User Centered Design (UCD) methodology.

Moreover, we have used several methods from the Design Thinking (DT) methodology into the phases of DCU methodology, in order to promote the creativity and empathy in the thinking of our further software developers. Then, during the 2009 we have integrated techniques from the creativity area with techniques of the design of interfaces from the Human-Computer Interaction (HCI) area. So, from the creativity area, we used the DT [3,4,5,6,7] as a creative process based around the "building up" of idea. However, from the HCI area, we used the UCD methodology as a design philosophy, in which needs, wants, and limitations of the end user of an interface take special attention at each stage of the design process [8,9, 10, 11, 12]. This last learning activity was carried out in the design and development of the projects selected by students with the objective to increase the significant learning.

This paper is organized as follows: first of all we will present both methodological approaches, DT and DCU, then we will show how we have integrated the methodologies into an learning activity carried out with students of Human Computer Interaction subject of the Computer Science Engineering.

II. Design Thinking (DT) methodology

DT can be described as a discipline that uses the designer's sensibility and methods to match people's needs with what is technologically feasible. It is based on the idea of the designers has a singular way to confront the innovation: "a protocol to solve problems and to discover new opportunities". So, the principles and tools used to design objects could be applied to "design" services or new solutions to complex problems. However, DT is not related with how to "design" products, on the contrary, is about how to "apply a methodology" of design and about certain skills that designers has to solve complex problems that need a creative more than analytic thinking.

This human-centric methodology integrates expertise from design, social sciences, business and engineering. High performance project teams are capable of simultaneously applying these different points of view. It creates a vibrant interaction environment that promotes iterative learning cycles driven by rapid conceptual prototyping.

However, DT is supported on the following principles:

1.*Empathy*: a deep, empathic and multidisciplinary observation about the user's needs, including their emotions.

2.*Imagination*: the optimistic search of solutions, thinking more in "the desirable" than "the possible".

3.*Experimentation*: the visualization of the possible alternatives through the experimentation, the game and the construction of visual stories (storytelling) in cooperation with users.

4.*Collaborative prototyping*: the application of techniques of collaborative prototyping to create models that help to visualize alternatives and to validate in group.

5.*Integrative thinking*: the capability of integration and synthesis of factors that influences the user's experience.

6.*Iterative learning*: the iteration of observation-creation-prototyping-validation process the time what it would be necessary until to find the best solution.

This methodology is based not only in the “usability”, but it is based in the “meaning” that people give to their context and the interaction with the product. In consequence, DT allows us to have a more complete vision of the user experience: emotional, cultural, cognitive, social, etc.

In addition, DT is a model of a creative thinking that could be applied in every area, following several stages:

1.To define the problem

2.To create and to take into account many options

3.To refine and to iterate with the selected options

4.To select the best option and to execute it.

We can summarized the DT in three large phases: 1) Understanding and observation, 2) Creation and prototyping, and 3) Testing and learning.

Tim Brown, the manager of innovation and design firm IDEO [13], defines the DT how a process centered in humans, and remarks the “human sight” of the designers. Moreover, he says that to know how the product is used is more important than the product does. It is applied a “activity-based approach” instead of based on the product. This way to see the context and the activity as a whole helps to discover new and innovative solutions beyond than the product.

On the other hand, the designers “learning by doing” into a laboratory where they can experiment in teams with several prototypes, putting in practice many creative techniques, such as: drawing, modeling, video recording, speed prototyping, storytelling (verbal and visual), photography and other techniques.

III. User-centered design (UCD) methodology

User-centered design, is a comprehensive software development methodology driven by a clearly specified, task-oriented business objectives and a recognition of user needs, limitations, and preferences. Information collected using UCD analysis is scientifically applied in the design, testing, and implementation of products and services.

There are several standards that define how to design and evaluate software products with the human-centered process approach, such as: ISO 13407 (explains the activities required for user centered design), ISO 16982 (outlines the types of methods that can be used), ISO/IEC 14598 (gives a general framework for the evaluation of software products using the model in ISO/IEC 9126-1).

Based on the principles of ISO 13407, we cited ten methods that are recommended when developing software for interactive systems:

0. Assessment of needs

1. A stakeholder meeting

2. Context of use

3. Task scenarios

4. Evaluating an existing systems

5. Usability requirements

6. Paper prototyping

7. Style guide

8. Evaluation of prototypes

9 Usability testing

10.Collection feedback from users after release to inform any redesign.

Moreover, UCD is an iterative process where we have to develop several techniques in different phases:

a) User Analysis: A user analysis is generally conducted before project planning has begun, or during the early stages of a project. In cases where no formal project has been established, a user analysis may be conducted before project planning to provide business management with an understanding of the workplace that can help to determine if there is a need for systems development. For projects that are just beginning, the workplace evaluation may be used to help define the project scope and determine the project approach.

b) Task Analysis: Task analysis should be conducted during project planning to help define the project scope and determine the project approach. However, the task analysis cannot be conducted until after the business objectives have been defined. The task analysis may be continued through the early stages of requirements analysis.

c) Information Architecture and Initial User Interface Design: The information architecture and initial user interface design can be completed at a number of different points in the design process.

d) User Interface (UI) Prototype: The UI design is generally refined and the UI prototype completed as requirements definition is finished and system design begins.

e) Usability Testing: Usability testing can be conducted as soon as a working UI mockup or prototype is available. The earlier usability testing is done, the more effectively problems found in the testing can be addressed.

f) User Interface Specification: Generally, the UI specification is a living document that is begun as soon as the first UI concepts are created, and is completed once the final UI design is finished.

As we showed above, we can observe that both methodological approaches match not only in the conceptual part besides in the methods, techniques and phases. For this reason, we propose an integration of both, focused on which techniques from the creativity area of the DT could be useful in the UCD phases.

IV. Integration of techniques: creativity in design

In order to start to work with the DCU methodology, students has to build a conceptual map of a project selected by themselves. The conceptual map given initially by the tutor, has the hole information about the methods, techniques of DCU and usability, organized in phases. This conceptual map will be building collaboratively in group under the supervision of the tutor. Each phase of the conceptual maps has one or more deliverables and the techniques applied must be selected adequately in each case, depending on the project of each group.

Regarding to the integration of the DT methods into the DCU methodology, specifically we have integrated the following in the phase of the design: a) Creative exploration (to look for quantity, ideas), b) Building and hands thinking (prototypes) and c) Simulation and role playing (interactive situations).

The "building games" using the game thinking based on building and where the learning is a sub product of the game. In this kind of games, the ideas are explored through prototypes, both in the design and with the physical objects, allowing the experimentation in the design [Fig. 1].

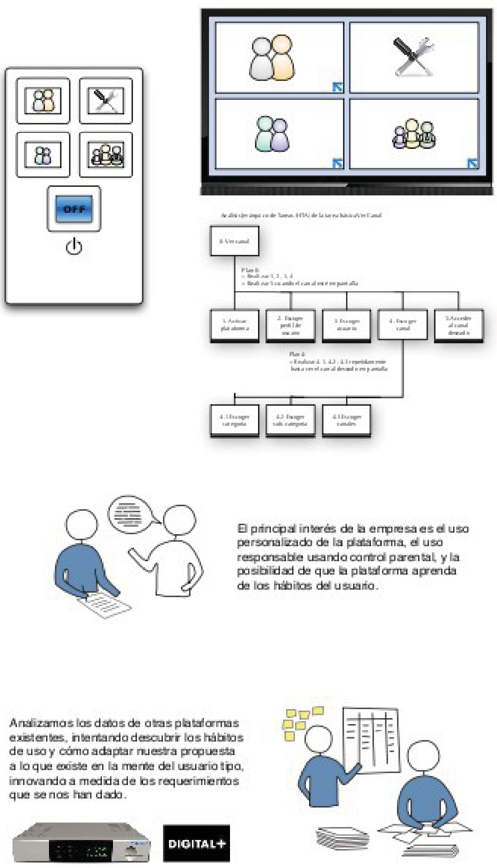

Figure 1. Example of a group proposal -DCU methodology.

In the case of the designers, this "building games" is denominated "to think with the hands" and it is achieved with "low cost and quality prototypes". This game allows to find solutions through prototypes and to carry out the designer's thinking to the real world quickly.

On the other hand, when we talk about to design something that is not a physical object but it is a system of interactions, we can use the "role playing" [14,15]. The role playing is very useful to think in experiences, to put us into the situation that we are designing and to project us in this situation. We can said that through the role playing we can achieve the "empathy of the designer", because the designer can put himself in the place of users of its designs and can imagine the situations where the designs will be used. It is so important in the instruction of further designers, because they must try the proposed solutions and the "role playing games" are very useful as "prototypes of situations" [Fig. 2].

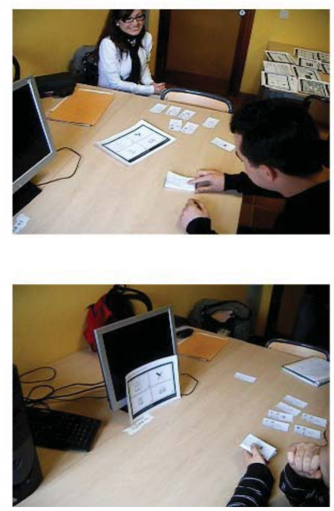

Figure 2. Testing prototypes in the laboratory.

V. Conclusions

In this paper we have presented an learning activity to teaching DCU methodology using some techniques from the DT methodological approach. Through this kind of activities we also provided an overview of the main HCI techniques and methods illustrating that the user target and the methods used affect the end design. Our main objective with this kind of activities were to promote the creativity and empathy in the further designers of software, showing the key steps of a UCD process in an enjoyable and informal setting. We are absolutely convinced that we need to increase the creativity thinking of our students in order to improve their capabilities to produce innovative solutions and to create products and services adapted to real needs of users.

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Toy Design Experience:

Improving Students' Motivation and Results in a Final Year Subject

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***Abstract*— In recent years educational gaming has been progressively perceived as a very effective tool for improving teaching-learning activities in higher education. The use of such play-based methodologies for engineering education can promote several practical and communication skills of great value for students' future professional development. At the same time it greatly helps to motivate students and make them more aware of their own capabilities and the learning process.**

This paper details the application of a play-based methodology for improving students' results and motivation in the subject "Development of Plastic Products". The active learning strategy consists in assigning student groups different toy development tasks, so that they can apply the design concepts learned and present their results in public. It is thereby hoped to promote a set of abilities that are ever increasingly valued in the industrial and business world, such as teamwork, creativity and communications skills.

Results have been compared with experiences from previous years, linked to the development of conventional products. The results show that carrying out a monographic experience on "Toy - Design" has promoted students' satisfaction, motivation and results. Some ideas for future improvements, mainly based on students' opinions, are also discussed.

Keywords: Learning through play, Active learning, Motivating students, CAD-CAM-CAE Tools, Rapid Prototyping Technologies.

I. Introduction

The subject "Design and Manufacture with Plastic Materials", taught in the 5th course at Universidad Politécnica de Madrid (UPM) as part of the Mechanical Engineering Degree, has been designed to fit in with the trends towards educational innovation and active learning set out within the framework for implementing the European Higher Education Area (E.H.E.A.) [1] following the purposes of the Bologna Process.

With this process implementation, higher education systems in European countries should be organised in such a way that:

- It is should be easy to move from one country to the other (within the European Higher Education Area) for the purpose of further study or employment.
- The attractiveness of European higher education is increased so that many people from non-European countries should also come to study and/or work in Europe.
- The European Higher Education Area should provide Europe with a broad, high quality and advanced knowledge base, ensuring the further development of Europe as a stable, peaceful and tolerant community benefiting from a cutting edge European Research Area.

The active learning strategy proposed in our subject consists in assigning groups of students different product development tasks, so that they can apply the design concepts learned to real problems, and then present their results to their fellow-students. It is thereby hoped to promote a set of abilities that are ever increasingly valued in the industrial and business world, such as teamwork, creativity and communications skills (ABET Professional Skills) [2].

The tasks begin with an analysis of existing products and end with the production of prototypes. This means that the new Rapid Prototyping Technologies [3] available in the UPM's "Product Development Laboratory" can be applied for teaching purposes, thereby implementing a teaching-learning method that at all times promotes active student participation.

The most important educational innovation objectives of this experience are:

- To enable students to experience a complete product development, from the conceptual design stage up to carrying out tests on a physical prototype.
- To follow the stages really used in industry, when it comes to designing and manufacturing new products.
- To encourage students to participate actively in their own learning process.
- To emphasise the importance of teamwork and finding solutions reached together.
- To continually induce students the use of critical thinking as essential tool for solving problems.

During course 2008-2009 the development experience was focused on "Toy design", as a way for improving student's motivation and results through play-based activities. Below are explained the tools used and methodology followed for supplementing the teaching of theory with the development of applied tasks, together with the results of this teaching experience.

II. Technologies and Tools Used

The use of "CAD-CAM-CAE" tools (computer aided design, manufacturing and engineering tools) is essential in any industrial machine or new product development process. The experience described has a highly praiseworthy teaching aim since it motivates students to use the different design and calculating tools used in mechanical engineering available in the Machine Engineering Division of the UPM, such as:

- CAD programs (Solid Edge, Catia, Inventor, Rhino), for modelling the different parts of a machine in 3D and obtaining the files needed to manufacture rapid prototypes.
- CAE programs (Solid Edge, NX-6 Siemens, I-DEAS), to undertake the simulations of kinematic function. In order to check both the parts design and the appropriate selection of materials, programs for finite-element calculation are also used (ANSYS, NX-6 Siemens, I-DEAS, Moldflow).
- CAM programs (Catia, Moldflow Mold Adviser), in manufacturing simulations and mould development for thermoplastic materials injection.

The Machine Engineering Division also places various "**Rapid Prototyping Technologies**" at the students' disposal so that they can materialise their designs, particularly:

Stereolithography.- A technology based on the possibility to activate a polymerisation reaction in an epoxy resin in a liquid state by projecting a laser beam, its power and frequency having been adapted to the type of resin. The laser gradually "draws" layers on the surface of the liquid resin, following a path marked out by the CAD 3D file containing the part geometry. The monomers in a liquid state, on being exposed to ultraviolet radiation polymerise and become solid. The operation is repeated until the end part has been obtained in epoxy resin by the successive superimposing of polymerised layers (Figure 1). The parts obtained by this process are particularly suitable for checking the parts visually and for size.

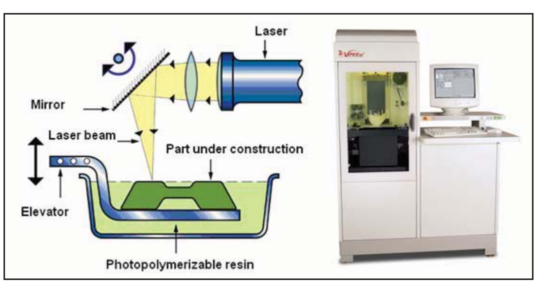

Figure 1. Stereolithography process and machine example.

Vacuum casting in silicone moulds.- The initial models or stereolithography parts can also be used for obtaining flexible silicon moulds which are subsequently used to obtain polyurethane resin replicas that are more resistant and suitable for working trials. These resins reproduce the mould cavities with great precision thereby obtaining working prototypes in materials similar to those of production.

These technologies serve to complement the "CAD-CAM-CAE" tools, enabling physical parts to be obtained in a few days, directly from designs carried out with the aid of a computer. Design iterations can be reduced and optimised, and therefore, production start-up accelerated, which means these technologies are highly valued in industry and so are very positive for training students.

This use of rapid prototyping technologies as a teaching aid is of recent appearance. Among some of the most innovative experiments it is worth highlighting those carried out in technical schools such as the "Massachusetts Institute of Technology" [4], the "Western Washington University" [5], the "Rose-Hulman Institute of Technology" [6], the "Massey University" [7], the "Universidad Simón Bolivar" [8] and the "Universidad Politécnica de Madrid" [9], [10].

In all of these schools, students have experienced the different product development stages: conception, design, simulation, analysis, manufacturing and tests, using tools such as Mechanical Computer Aided Engineering ("MCAE") and the most recent Rapid Prototyping and Manufacturing Technologies ("RP&M").

The application of these computer aided design, engineering and manufacturing technologies to teaching the subject "Design and Manufacturing with Polymers" during course 2008-2009, supporting the already mentioned "Toy Design Experience", is explained below.

III. Teaching - Learning Methodology

At the beginning of the subject, the students are divided into teams of three (exceptionally four), which are given different products to be developed. Products are chosen that can be mass produced by thermoplastic materials injection and which allow the knowledge acquired in theory classes to be developed in a practical way.

During the 2008-2009 academic course, a total of 71 students have approached the complete development of 23 different products. To promote motivation among students the experience was centered in toy desing and each group should find and design a different toy.

Studies do not include steel mould manufacture or injection machine tests due to the high investment costs and the time that would be involved. However, all injection simulations performed using "Moldflow" type programmes are very positively assessed. The stages that must be got through by students are enumerated below and are those corresponding to the development of a new industrial product [11], all of which helps to give a boost to the teaching aims proposed:

1. Approaching the problem and analysing the specifications.
2. Conceptual design and choosing materials and components.
3. Detailed design, including explanation of calculations.
4. Solution analysis and mould filling simulations.
5. Prototype manufacture.
6. Assembly and working trials.
7. Verifying results and drawing up conclusions.
8. Mould design.
9. Comparing and evaluating results.

A) Approaching the problem

The students gather information on their products and analyse existing solutions together as a prior stage to the design tasks. In any development process an exhaustive information search needs to be done on the product, and a comparison made between similar solutions that exist, in order to be able to prepare an appropriate planning schedule and fully and exactly define the aims.

The result of all this will be a list of requisites with the basic information for the project (desired toy to be designed). At every instant students must endeavour to comply with these basic specifications (or mandatory requirements). Moreover, it is important to make a list of pretensions (or requirements to be taken into consideration whenever possible) that will form a basis of negotiation with the client and increase competitiveness and profits.

B) Conceptual design

The teams continue to work on the list of requirements to identify any crucial problems and choose the best solution for each one, paying also attention to manufacturability, time optimization and costs reduction.

Using CAD programs and drawing sketches by hand (as shown bellow) sees the beginning of the work to obtain a pre-design of the different parts while comparing any possible alternatives. In this way, materials are chosen according to the initial estimations of resistance needed for the different components and parts. Figure 2 shows as example the conceptual design.

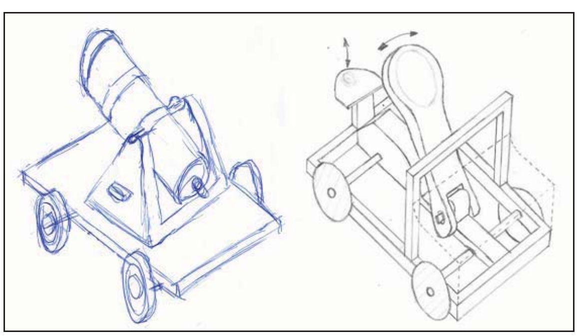

Figure 2. Different examples of conceptual designs.

C) Detailed design

Once the most appropriate solution has been chosen from the different pre-designs, the different parts must be exactly defined. Following the concepts explained in the theory classes, the students must use a design approach oriented towards manufacture and assembly, in line with the current trends in Concurrent Engineering. The results of some different tasks are shown in Figure 3.

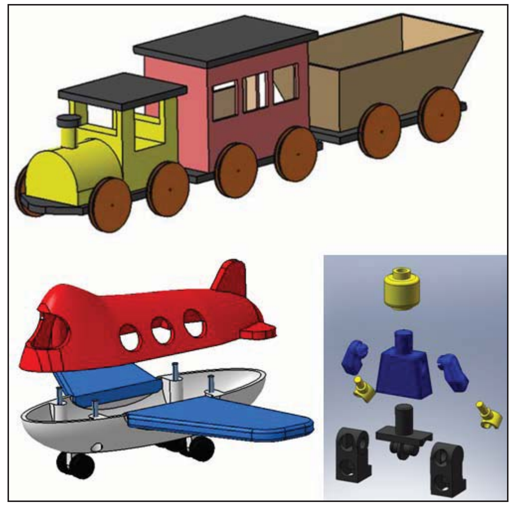

Figure 3. Different examples of detailed designs.

To check that the chosen materials are suitable, the estimates need to be compared, using simplified theoretical models, with the information provided by Computer Aided Engineering programs. The use of thermoplastic material injection simulation programs, which are habitually used prior to the construction of the moulds, is also important, in order to check that the choice of materials and injection conditions are appropriate, as well as an optimum distribution of the cavities in the mould, material inlets, filling channels and cooling system.

The teaching aim is worth emphasising, since it motivates students to use the different computer design and calculation tools used in mechanical engineering, as explained above. The basic concepts for employing CAD Tools are explained in previous subjects during their first years at Universidad Politécnica de Madrid. However 5 training sessions using the CAD Program “Solid Edge” are placed at students’ disposal at the beginning of the subject, so that every student has the opportunity to review the main concepts.

Moulding simulations are carried out in order to choose the optimum (theoretical) injection point or to evaluate times and temperatures obtained when filling the mould cavities. These are important studies for optimizing subsequent production processes. Additionally, Figure 4 shows different finite-element calculations in order to check both the parts design and the appropriate selection of materials.

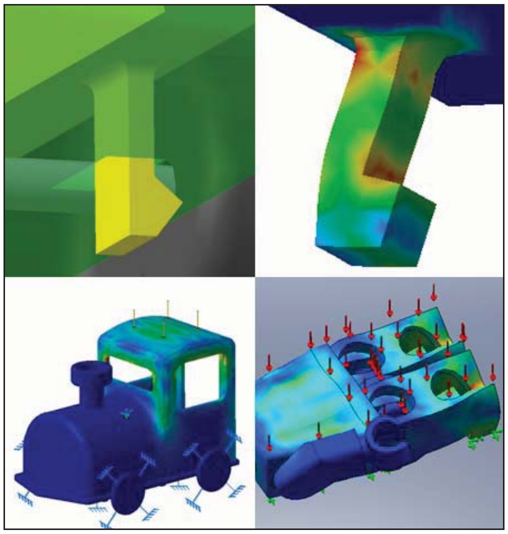

Figure 4. Different F.E.M. simulations for design validation.

D) Prototype manufacture

Using the CAD files provided by the working groups, and once the appropriate calculations have been made, the prototypes are produced by stereolithography technology as explained before. Using the rapid prototyping technologies available in the UPM's Product Development Laboratory (http://www.dim.etsii.upm.es/ldpdim/) brings students closer to these new technologies now becoming more widespread in industry, thereby giving added value to their training and allowing them to physically check the validity of their CAD designs.

Figure 5 shows some of the prototypes made for visual and assembly checks, paying special attention to tolerances, any possible interferences and empty or useless spaces.

Additionally Figure 6 includes a schematic diagram of the development process followed, from initial drafts to final pre-production prototype.

Figure 5. Different examples of manufactured prototypes.

Figure 6. Development process followed.

They also enable certain working trials to be performed, but the fragility of the epoxy resin materials of which they are made has to be taken into account. For tougher trials, a second prototyping stage can be carried out, involving the manufacture of silicone moulds for polyurethane vacuum casting.

During course 2008-2009 the costs for manufacturing the 10 prototypes of the selected best toy-designs laid around 2500 to 3000 euros.

The UPM's Product Development Laboratory, whose main objectives are to provide prototyping solutions for industrial requirements and to assist teaching-learning activities at University, helped at every moment with the costs not covered by the previously explained initiatives.

E) Verifying results and conclusions

Once the prototypes have been checked, the next stage is for the teams to make their final results public, and justify the decisions made in front of their teachers and fellow-students. The joint discussion on the different tasks performed means that each team learns from the work of their fellow-students thereby enhancing the teaching aims.

IV. Main Results of the Experience

At the end of the course, a survey was made so as to assess the quality of the teaching experience, based on students' satisfaction and understanding about their own knowledge. The results are summarized on Table 1 and explained further on.

TABLE I. Students' Personal Opinions

Students' opinion on different aspects	**Mean score from 1 to 5:**
Knowledge acquired compared to other Mecanical Engineering subjects	3,81
Comprehension acquired related to the product development process	**4,03**
Knowledge acquired regarding polymer technique and design	3,98
Knowledge acquired regarding CAD – CAE – CAM tools	3,94
Knowledge acquired regarding RP&M technologies	3,60
Importance of teamwork activities within the subject	**4,40**
Students' workload	3,77
Possibility to apply the knowledge acquired in professional future	3,90
Coherence between explanations and assessment procedure	**4,18**
Overall impression of the subject	**4,34**
Toys as theme proposed for the products	**4,42**

The results show students' overall satisfaction within the subject and the very positive perception of their own acquired knowledge. We believe the theme proposed "Toys" for the design team-works has enormously helped to promote students' motivation and final qualifications as shown in the assessment chapter.

Some future actions including visits to enterprises and technological centres, dedicated to product design and development, will help to increase their opinions on usefulness of the acquired knowledge for their future professional development

Regarding the play-based methodology, 100% of students answered positively to the question "Have you enjoyed your experience in the subject?" and 100% of the students answered positively to the question "Do you believe enjoyment helps general motivation and improves final results?".

Among other personal opinions and some suggested improvements to the subject were:

- "It would be interesting to make more complex machine prototypes or products by working together with different teams."
- "Producing a second stage of prototypes would enable the solution to problems found in the first stage to be checked, and the design improvements proposed to be verified."
- "The nicest thing about the subject is being able to see and touch your own designs."
- "The workload required to develop the product is excessive."
- "The number of theory classes should be reduced and the practical part of the subject increased."

Regarding the actual interest of using prototypes, a survey was carried out, after prototype assembly and trials, so as to ask students' personal opinion about rapid prototyping technologies and the importance of prototyping in order to validate the designs. The main results are set out below in Table 2.

TABLE II. Benefits of Using Prototypes

Evaluation of prototypes and RP&M technologies	**Mean score from 1 to 5:**
Importance of prototypes as support tool	4,625
Quality of manufactured prototypes	3,875
Prototypes for detecting design errors	4,625
Prototypes as complement for CAD tools	4,5
Importance of redesign according to prototypes	4,5
Interest of the prototypes for teaching aims	5

An additional survey was made in order to quantify students' real dedication to the subject and validate the number of European Credits assigned to the subject (between 25 and 30 hours of personal student work per credit). The results are included in Table 3 at the beginning of the following page.

A total average of dedication of 84,8 hours/student was obtained, which is in line with the 3 European Credits assigned to the subject (between 25 and 30 hours per credit), and combines attendance at theory classes with individual work in accordance with the European Credit Transfer System (ECTS) guidelines.

The balance between individual and teamwork is also noteworthy with 47% dedication to individual activities and 53% dedication to teamwork activities.

TABLE III. STUDENTS' WORKLOAD

Dedication to the different work stages	Total average (hours per person)
Formal lessons (35 scheduled hours, non-compulsory attendance):	32,54
Attendance at tutorials:	7,52
Product search and prior studies:	2,23
Conceptual design:	11,68
Detailed design:	18,95
Prototype assembly and trials:	6,44
Total	**79,36**
Dedication to editing and presenting papers	**Total average (hours per person)**
Preparing reports and presentations:	4,24
Public exposition:	1,5
Total	**5,74**
Work distribution (Individual / Group):	**Percentage (%)**
Percentage of INDIVIDUAL WORK:	47
Percentage of TEAMWORK:	53

From these results it can be concluded that the scores given by students are positive, particularly the scores regarding knowledge acquisition and satisfaction in obtaining prototypes of the designs produced. However, there are still certain points that need improving in the general approach to the subject and in the participatory working methods.

Finally we would like to note that the number of hours dedicated by teachers to monitoring, listening to presentations and marking student projects is considerable.

The number of hours dedicated to tutorials has also increased considerably with the introduction of application tasks, as questions had to be answered in a personal way, due to the great differences between the proposed toy designs.

For future experiences we will consider the establishment of an active tutorial plan, including students that have already studied the subject and can help their younger companions, so as to provide students with a more personal teaching.

V. ASSESSMENT OF ACTUAL BENEFITS

In order to assess actual benefits of the play-based methodology proposed, a comparison between final marks is included here.

Students' personal scores on satisfaction within the subject and understanding about their own knowledge have already been analyzed. Now we focus on teacher's evaluation of students' actual knowledge regarding product design with plastic materials.

During 2007-2008 course a total of 57 students coursed the subject and during 2008-2009 course the total number increased to 71. In this way teacher's workload also increased, but for assessment purposes we may consider both groups as comparable ones (both in size and previous knowledge regarding the subject).

In both cases assessment was mainly based on results from team-work / designed product (up to 80%), with some influence on personal activities during formal lessons and attendance (up to 20%).

Additionally the difficulty of developed products is considered to be similar, as well as the criteria for marks assignment, for both courses. Among most valued factors are:

- Originality of the proposed product.
- Systematic design and development procedure.
- Systematic comparison of possible solutions.
- Application of the design concepts explained.
- Comparison between calculations and simulations.
- Assembly and trials of prototypes.
- Final functional result.
- Final esthetical result.
- Overall product difficulty.

The results from such comparison are included in Figure 7 and subsequently explained.

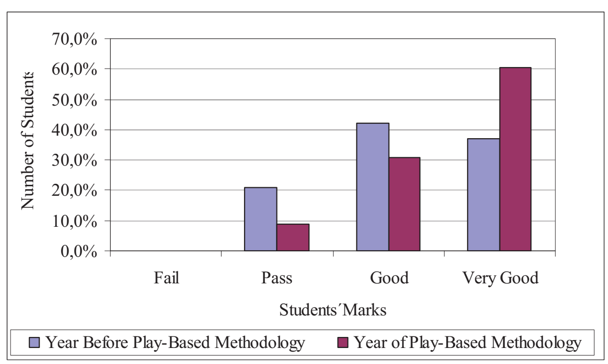

Figure 7. Evolution of students' marks with the introduction of play-based methodology.

From these results it can be noted that the proportion of very good developments increased from around 36% to around 61%. We believe such increase is completely linked to their additional motivation, and consequent workload devoted, due to the proposal of a monographic on "Toy design" (as also stated by students themselves in the satisfaction surveys gathered).

VI. Conclusions and Future Proposals

Learning through play has proven to be a great success, especially in areas such as primary education, foreign language courses and artistic education. In fact, several degrees on pedagogy include subjects for training future teachers in tasks linked to play preparation and its benefits for students.

However in recent years educational gaming has been progressively perceived as a very effective tool for improving teaching-learning activities in higher education. The use of such play-based methodologies for engineering education can promote several practical and communication skills of great value for students' future professional development, as our teaching-learning toy design experience has proved.

At the same time it is possible to increase students' motivation and to make them more aware of their own capabilities and the learning process. As a result there is an increasing interest among scholars in investigating this area, so as to quantify its actual effect on global learning and in order to apply its principles in a more efficient way.

Additionally, undertaking problem based learning and teamwork activities, where students can experience the complete development of a product or machine, following the stages used in the industrial world, brings them closer to future work experiences. Aspects such as active decision making, weighing up alternatives, self-teaching, time and cost planning, the application of regulations, design in line with commercial elements or contact with suppliers, are given an enormous boost.

Student learning, throughout projects such as these, benefits greatly from the use of computer aided design, manufacturing and engineering tools, (CAD-CAM-CAE tools) highly esteemed by companies dedicated to the development of machines and products.

It has been shown that the use of rapid prototyping technologies enables students to come into contact with modern manufacturing technologies that are becoming widespread in Industry thereby giving added value to training. It is, in itself, a way of learning, since it lets designs be tested by performing assembly and working trials with physical parts.

The experience implemented for the subject "Design and Manufacture with Plastic Materials" may be extended to numerous other subjects in Mechanical Engineering so as to obtaining integrated teaching in these subjects. The results have been highly satisfactory, both for students and teachers, all of which motivates us to continue with the experience and improve it in future courses.

The correspondence between students' dedication and the European Credits assigned to the subject is very satisfactory, as can be seen from the surveys' results.

We believe students' attendance, motivation and results have been promoted through play-based methodologies, specially taking into account that the subject is part of the final year course, when many students prefer active learning activities and assessment through development works, rather than traditional lessons and final exam.

We hope the explained teaching methodology and assessment process can be of help for future researches on these areas.

Acknowledgments

Authors would like to thank students for their interest in the subject and for the quality of application works carried out. The images shown are results from their designs and prototypes, within the subject "Design and Manufacture with Plastic Materials" during academic course 2008-2009. Such images have been included here also as a way for motivating future students.

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The developing of personal and professional skills in automotive engineers through university competitions

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Reflections about Teaching Engineering Graphics: Knowledge and Competencies Management

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Measuring collaboration and creativity skills through rubrics

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The developing of personal and professional skills in automotive engineers through university competitions

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Abstract—**Promoting personal and professional skills is becoming an issue of interest and major concern in university environments and this, in turn, is being driven by the demands of business. In this paper the authors, teachers from UPM and ISAT, present the basic features of the Formula SAE project and some other international competition such as Eco-Shell Marathon, Formula Baja or Formula Low-Cost, and analyze the way these competitions helps to promote 24 basic skills in the students, compared to other activities carried out during their engineering degree courses.**

Keywords-component;, automotive engineering, skills, competition, Formula SAE

I. INTRODUCTION

Universities are ever more concerned to open up students' training perspectives towards aspects that are not always a part of their studies, such as enhancing their personal and professional skills [1]. Thus, for several years the experiences of educational programmes have been regularly published where the enhancement of theoretical-practical knowledge is only one of the goals sought. E. Bowen [2], and D. Chadha [1][3], for instance, raise the issue of studying and assessing skills promotion in different university departments in the United Kingdom.

In a simplified way what is understood by skills is "a combination of knowledge, abilities and attitudes that are suited to particular circumstances" [4]. De Miguel et al [5] offer a fuller definition when they say, "by skills is understood the set of knowledge, abilities, behaviour and attitudes that favour work being done properly and which the organisation is interested in developing or recognising in its co-workers when it comes to achieving the company's strategic goals".

The European Commission [4] has recently highlighted eight key skills for continuous learning as a goal to be achieved by every citizen who aspires to "live and work in the new information society". These are communication in the mother tongue, communication in foreign languages, mathematical skills and basic skills in science and technology, digital skills, learning to learn, interpersonal, intercultural and social skills, citizens' skills, the spirit of enterprise and cultural expression.

The second definition of skills makes reference to the four successive psychological learning levels: knowledge, ability, behaviour and attitude. In the light of these, it can be said that, excepting some initiatives, university training has been focused mainly on strengthening technical knowledge and abilities, since these first two levels are the ones that can be attained with the traditional system of classroom lectures.

So, a genuine promotion of personal and professional skills has not been a generally sought after goal, since trying to make students change their behaviour and attitudes involves using other teaching methods that are usually more costly regarding time, space and personal resources, although on occasions these methods simply need to be more imaginative.

Likewise, student assessment has usually been based almost exclusively on their knowledge and skills in solving problems on paper in an environment where time is scarce, where information is restricted to the data given in the written instructions and a lack of sources for consultation. Therefore, certain personal qualities such as memory and speed are overvalued to the detriment of other qualities which are at least just as important.

However, the human resource managers of the major companies rate basic personal skills very highly in the graduates that they take on; skills such as the ability to work in a team, leadership, self-motivation and team motivation, a capacity for self-learning, etc, giving less importance to the level of technical knowledge possessed at the time of their being taken on [6], [7].

The study entitled "Tuning Educational Structures in Europe" [8], financed by the European Commission reveals the large discrepancies existing between the priorities given to different skills and personal abilities by university teachers, new graduates and employers. A summary of this study is shown in Table I.

Aware of all this, those who designed the great European university paradigm (Bologna Declaration [9]), recognise the importance of introducing activities into the training programmes that help to promote abilities and skills in students.

TABLE I. ASSESSMENT OF THE ORDER OF IMPORTANCE OF DIFFERENT PERSONAL SKILLS AND ABILITIES AS SEEN BY GRADUATES, ACADEMICS AND EMPLOYERS [8].

Personal skills and abilities	Academics	Graduates	Employers
Analytical and summarising skills	2	1	3
Ability to apply knowledge in practice	5	3	2
Basic general knowledge of the study area	1	12	12
Basic knowledge of the profession	8	11	14
Oral and written communication in own language	9	7	7
Knowledge of a second language	15	14	15
Basic computer usage skills	16	4	10
Research skills	11	15	17
Learning skills	3	2	1
Capacity for self-criticism and criticism	6	10	9
Ability to adapt to new situations	7	5	4
Capacity to generate new ideas	4	9	6
Decision making	12	8	8
Interpersonal skills	14	6	5
Ability to work as part of an interdisciplinary team	10	13	11
Appreciation of diversity and multiculturalism	17	17	16
Ethical commitment	13	16	13

The European Convergence process is now bringing about a change in the outlook of university teaching staff. Educational actions in the University in future years will need to be channelled towards becoming adapted to the European Higher Education Space, in addition to achieving an enhancement of training programmes and the incorporation of new goals aimed at developing personal and professional skills.

II. PRINCIPAL SKILLS OF AUTOMOTIVE ENGINEERS

In this context, a group of teachers and professors from Madrid Polytechnic University, UPM, belonging to the University Institute for Automobile Research, INSIA, being aware of the need to introduce changes into the teaching activities that would help to promote the most demanded skills by a sector as competitive and complex as the automotive sector, decided to get to know these skills at first hand. One of the reasons for conducting the study was their conviction that these skills might not literally coincide with those demanded by other sectors.

If they should know which skills the undergraduate and graduate students should need to acquire and develop, it would help them to organise the teaching activities and adapt the available methods and resources. It would also help them to set the goals to be attained by teaching staff as well as providing them with the tools needed for them to attain these goals.

A two-round Delphi questionnaire[1] was used to conduct the study which was directed towards professionals in the major companies in the Spanish automotive sector. These companies are divided into two large groups: vehicle manufacturers and component manufacturers. Thus, since their tasks are highly complementary but different, the experts were questioned as to the most important abilities and skills for new engineers taken on in their companies as well as in the complementary ones. In other words, each vehicle manufacturing company professional was asked their opinion about the most important skills for a new engineer in a vehicle plant, and also for one in a component plant; and vice-versa.

The procedure followed was as below:

- A "Panel of Experts" was set up, comprising 8 professionals representing different posts in each of the two types of company.
- A draft questionnaire was prepared which gave a choice of 30 personal and professional skills sought after in an automotive engineer. These skills were submitted to the "Panel of Experts" for approval so they could then be finally included in the questionnaire.
- The questionnaire was sent to selected persons in the automotive industry ("Consultative Panel"). 24 professionals were chosen in all. Mainly those holding technical positions and human resources managers in both types of company.
- A month and a half later 21 replies were received (87.5%) with an average response time of 23 days. During this time those polled were sent two reminders by e-mail until the survey was answered.
- The questionnaire was then dispatched a second time to the experts so they could ratify or change their responses in the light of the average given by the experts as a whole.
- Finally, after another month and a half's wait, 20 replies were received (83,3%), with an average response time of 17 days, where two reminders were also sent out.
- A statistical analysis of the survey results was carried out and a final report written.

The results obtained are shown in Table II. The first column shows the importance given by a vehicle manufacturer to a new engineer working in a vehicle manufacturing company, and the second column the importance for workers in a components manufacturing company. The third and fourth columns are the responses from the components manufacturers.

In spite of the profound mutual knowledge of both types of company, the table reflects significant differences concerning the type of work that each person thinks is done by the others.

The responses from both sides are also quite a fair reflection of the situation in the Spanish sector, where vehicle manufacturers are mainly concerned with production and to a much lesser extent with vehicle design, whereas there is a much larger and dynamic industrial fabric devoted to the design and manufacture of automotive components.

[1] The Delphi questionnaire was developed in the United States in the 60s. Its name comes from the famous Greek oracle in Delphos, which the ancient Greeks turned to in order to know their future. It is commonly used to conduct forecasts among professionals using surveys that are sent out in two rounds: in the second round the expert is informed of the response of the other persons polled, giving them a chance to change their initial response.

TABLE II. THE SKILLS AND ABILITIES MOST APPRECIATED IN THE AUTOMOTIVE SECTOR (RATED 0 TO 4).

	Skills and abilities	Vehicle Manufacturer		Components Manufacturer	
		Vehicle Man.	Comp Man.	Vehicle Man.	Comp Man.
1	Team leadership	4	4	4	4
2	Team motivation	4	4	4	4
3	Responsibility at work	4	4	4	4
4	Teamwork	3	4	4	4
5	Capacity for innovation	4	3	3	4
6	Common sense	3	4	3	4
7	Communication skills	3	3	4	4
8	Negotiating skills	3	3	4	4
9	Financial awareness	3	3	4	4
10	Capacity for initiative	3	3	3	4
11	Ability to convince	3	3	3	4
12	Sales ability	2	3	3	4
13	Emotional Intelligence	3	3	3	3
14	Non-verbal communication	2	3	2	3

The most appreciated skills were leadership and team motivation, responsibility at work and teamwork. Also highly rated are the capacity to innovate, and communication and negotiating skills.

III. THE AUTOMOTIVE UNIVERSITY COMPETITIONS FOR ENGINEERS

Nowadays, there are several automotive competitions oriented to undergraduate students in which the multidisciplinary groups of each university have to build a vehicle. Each competitions have different objectives on education as is teamwork, leadership, innovation, solve problems, among others. The most important are the following ones:

A. The Formula SAE competition

In 1982 engineers from Ford, DaimlerChrysler and General Motors, grouped together in the SAE (Society of Automotive Engineers), in the United States, being aware of how little newly graduated engineers were adapted to automotive companies, designed a competition for universities throughout the world, which involved conceiving, designing, manufacturing and competing with a single seat formula-type vehicle. This competition was called the Formula SAE.

They were of the opinion that this challenge would serve to accelerate engineering students' professional profiles, forcing them to work as part of a team, with high levels of communication, responsibility and motivation, forcing them to use in their work a large part of the knowledge acquired in their degree.

For there to be project uniformity and equal opportunities in the competition, the SAE sets strict standards as to the design and manufacture of the different vehicle parts in addition to severe safety standards. In spite of this, the participants enjoy a wide autonomy and capacity to innovate, as can be seen in the differences in the models from each university.

Each university must present a project as if it involved a company that manufactured 1000 vehicles per year for an amateur public competing at weekends, and with a cost of less than 25,000$.

The main condition refers to vehicle power, restricted by engine cylinder capacity (maximum 600 cm3) and by a restricted air intake. Therefore, most machines use motorbike engines which are standard engines of around 110 HP, but by restricting the air intake their capacity is reduced to around 70 HP after appropriately designing the intake and exhaust with fluid dynamics programs and after electronically changing the engine torque and power curves.

Other restrictions refer to vehicle size (minimum 1,520 mm wheelbase, and minimum 9 m slalom track pass), which means that the vehicles are around 2,700 to 3,000 mm long. There is also an exhaustive materials check of the materials making up the chassis, and close attention is paid to safety and driving seat ergonomics.

Competition score cards are divided into two kinds: static and dynamic. Also, there are some preliminary tests that do not score, but need to be overcome in order to compete. Table III shows the tests together with a brief description of each one.

TABLE III. DESCRIPTION OF FORMULA SAE COMPETITION TRIALS.

Events	Points	Description
Preliminary tests	**0**	Pre-competition safety tests.
Technical inspection	-	General check of car by judges.
Tilt	-	Car inclination up to 60º checking its stability and that no type of liquid is leaking.
Brakes	-	Simultaneous blocking of all four wheels after a brief acceleration.
Noise	-	Check to ensure vehicle emits less than 110 dB under certain acceleration conditions.
Static	**325 in total**	Presentations and oral defence in front of the judges of technical solutions adopted.
Design	150	Technical defence of vehicle design and solutions proposed.
Presentation	75	Marketing presentation, convincing the judges to choose their car compared to the others.
Costs	100	Written report detailing cost of each part and component of the unit built.
Dynamic	**675 in total**	Different on-track trials with the single-seater.
Acceleration	75	Cover 75 m on a straight run in the shortest possible time
Manoeuvrability (Skidpad)	50	Manoeuvrability to run a 9 metre circle in both directions.
Sprint	150	Quick lap of the circuit
Endurance	350	Overall vehicle performance and reliability in 22 laps of a circuit.
Fuel	50	Minimum consumption in endurance trial
Total	**1000**	

As can be seen, this is an authentic engineering competition where in addition to vehicle speed and performance the project and the product achieved are also appreciated. In this competition the students have a totally leading role. They have to organise themselves, find the resources needed, administer project time, costs, etc, and all this under the supervision and advice of the advisory teachers and the Faculty Advisor. They have to design and build the parts by hand (the fewer purchased the better), and four of them must finally drive the car.

What is new about this project, apart from it being a new, innovative educational methodology where the vehicle is simply the means to get the best possible training, is the challenge posed to the students by having to take on and participate in an entire vehicle development life cycle. This can only be achieved by forming a strong working team, promoting active participation, the assumption of responsibilities, decision making and involvement in reaching a common objective. In exchange the student gets the satisfaction of being able to take the vehicle built by their own effort to an actual competition.

Currently, more than 200 universities throughout the world take part each year in the Formula SAE. For this it has been necessary to extend the competitions to other countries, like England, where it is called Formula Student, Australia, etc, as well as the original in Michigan.

B. The Baja SAE competition

Baja SAE is a university competition whose aim is to improve the preparation and education of young engineers through an event that simulates a real engineering project where students have to design, manufacture, test, and compete with an off-road vehicle.

The participating teams have to assume that they have been hired by a manufacture firm to build an off-road vehicle capable of competing in any field. The restrictions are on the design of chassis, and the engine modifications are prohibited, as the engine is the same for all teams. Unlike Formula SAE standards these restrictions limit the design and innovation in these areas, leaving the engineer's imagination for other areas of the vehicle. This, in turn, results in a reduction in costs and activities compared with Formula SAE. The target for selling the prototype is the non-professional weekend racer, as well as the Formula SAE, and the teams must develop a product that has high performance in acceleration, traction, with common parts and easy maintenance. It is a competition that also simulates a case study of the life cycle of a vehicle, where students also have to get organized sponsorship for their project.

The engine is a 10HP, and it is not allowed to make any changes or modifications. The overall dimensions of the vehicle recommended to be on lengths of 275cm are the track is restricted to a maximum of 190cm. The cage in the chassis is very limited in terms of innovation to ensure the safety at all situations, as in the event of rollover or impacting with another vehicle.

Is highly valued by the judges the manufacturing capacity with conventional tools that are available to anyone. Teams will be evaluated on design, and marketing costs (not all of Baja competitions own this event). In the dynamic performance, the students must demonstrate their ability to accelerate, steer, and drive the vehicle to finally be evaluated in endurance where they are able to repair the vehicle in the race. Table IV shows the events with a brief description of each one.

The Baja SAE competition began in 1976, and currently has 6 competitions in the USA, Brazil, South Africa and South Korea are involved in more than 250 university total more than 4000 students participating.

TABLE IV. DESCRIPTION OF FORMULA BAJA COMPETITION TRIALS

Event	Points	Description
Static Events -	**300 in total**	Presentations and oral defence in front of the judges
Design Report & Evaluation	150	Technical defence of vehicle design and solutions proposed
Cost Report & Cost Production	100	Writing report dealing cost of each part and component of the unit built
Presentation	50	Marketing presentation, convincing the judges to choose their car.
Dynamic Events -	**700 points**	**Different on-track trials with the off-road vehicle**
Acceleration/Speed	85	Cover 30m o 45m on a straight run in the shortest possible time
Traction/Hill Climb or Pulling Event	75	The traction event will be either hill climb or pulling an object
Manoeuvrability	75	Manoeuvrability including tight turns, pylon manoeuvres, ruts and bumps, drop-offs, sand, rocks, gullies, logs, and inclines.
Specialty Rock Crawl or Suspension Traction	75	A special event to test the vehicle on unique off-road conditions
Endurance	400	Maximum distance performed in 4 hours
Total Points	**1000**	

C. Eco-Shell Marathon

This university and college competition has the goal to compete with more efficient vehicle for a given distance. There are two categories, one corresponding to futuristic vehicles where reducing drag and maximizing efficiency is the major premise and the second category corresponding to four-wheeled vehicle using conventional or alternative fuels.

Competition rules limit the size in wheelbase, track and height of vehicles, chassis design (to ensure safety), the type of propulsion (it can be used combustion, fuel cell or solar) and deposit size is limited to 30cc to 250cc. limiting the size of engine to use. The following list outlines the types of fuel that can be used:

- Shell Unleaded 95 (Europe & Asia) / Shell Regular 87 (U.S.)
- Shell Diesel
- Liquefied Petroleum Gas (LPG)
- Shell Gas to Liquid (GTL 100%)
- Fatty Acid Methyl Ester (100% FAME)
- Ethanol E100 (100% Ethanol)
- Hydrogen

Vehicles must meet travel between 22 km or 25 km depending on the category in which they participate. The assessment of efficiency is done in accordance with a table of equivalence developed by the competition.

The aim of the competition is to simulate a real art project where teams work for a year designing and building a vehicle. The event organizers also want students to integrate, design and develop a product that is sustainable, that controls the energy used and that is concern about environmental protection. This target causes that the greatest number of team efforts are focused in engines, transmissions and aerodynamics.

D. Formula Low Cost

Created by ISAT in 2008 with the aim of extend these kind of competitions to universities all around the world, regardless their economic possibilities, Low Cost Formula is a competition aimed at extending university engineering education through the construction of a kart type vehicle. The main difference with Formula SAE is the budget, which can not exceed 2.000€ for its build, based on fixed prices of components.

In this competition the teams have to assume they have been contracted to manufacture a vehicle whose main feature is that it has not suspension. For the chassis, the rules establish that they must be designed to ensure the safety, and the materials allowed are only steel and aluminium. The engine can not exceed 12KW and are well worth the innovations that can be made. Although the size of vehicle is complete free, the possibilities with the 2,000€ restriction are limited.

As an engineering competition, teams valuation is done through a set of tests, both static (where it is evaluated the technical and cost features) and dynamic (where it is evaluated the track vehicle performance). The statics events have the aim to assess the designs, innovations and cost of the prototype. The dynamic events are composed of three: a classification, a sprint race (15 laps) and resistance (60 laps).

This competition also provides an opportunity for students to participate throughout the life cycle of a real project, in order to prepare engineers to manage projects, budgets and learn to work as a part of a team. Table V shows the events with a brief description of each one.

TABLE V. DESCRIPTION OF FORMULA LOW COST COMPETITION TRIALS

Event	Points	Description
Static Events -	**478 in total**	Presentations and oral defence in front of the judges
Cost Report	183	Writing report detailing cost of each part and component of the unit built
Innovations	183	Technical evaluation of innovations
Design	112	Technical defence of vehicle design and solutions proposed
Dynamic Events -	**441 points**	**Different on-track trials with the off-road vehicle**
Acceleration/Speed	75	Cover a straight run in the shortest possible time
Sprint	183	A event to classified the vehicle for the main event
Endurance	183	60 laps to a circuit
Total Points	**919 points**	

IV. THE PARTICIPATION OF THE MADRID POLYTECHNIC UNIVERSITY, UPM, ON THESE COMPETITIONS.

As previously stated, after selecting the Formula SAE as the project to be embarked upon by our students, in October 2003 the University Institute for Automobile Research, INSIA, was set up; the first Spanish Formula SAE competition team, called UPMracing. It was made up of about 35 students from the final courses in the School of Industrial Engineering of the UPM, and the Master's course in Automotive Engineering (Figure 1). In the years that followed, several students from other university schools joined in, like the Aeronautic Techniques and Industrial Techniques schools, what lead to important improvements in the performance (Figure 2).

Figure 1. The team in England with the UPM-01 and UPM-02 cars

Figure 2. Competition pictures with the UPM-03 and UPM-04 vehicles

At present the UPMracing has accumulated six years of experience with the same number of single-seaters built that have taken part in the 2004 – 2009 editions of the Formula Student in England.

From the beginning the project has been based on four principles that are a statement of the teaching method used:

- Learn by applying
- Learn by doing
- Learn in a team
- Learn by competing

Moreover, in order to maximise student performance and progress, a whole strategy of learning situations has been planned which participants must pass through during their period in the team, as it will be referred in next epigraph.

With the aim of reproduce similar conditions to the work carried out in real companies, the team has been organized in several departments according to the main systems of the vehicle. These divisions, supervised by a small team of teachers, conform an operative organisation whose chart is shown in Figure 3.

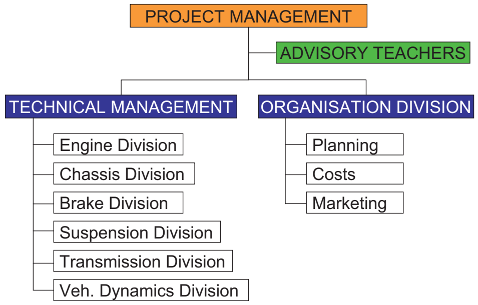

Figure 3. UPMracing team organisation chart

The students usually spend the last two years of their careers working at a division on the team: on the first one they do the training and computer design, and on the second the manufacture, testing and also attend the competition in England. Although there are planned two short non mandatory subjects and the most of them uses the work performed as the Final Career Project, the joining at the team is completely voluntary and the students have to develop the most of the work on their free time.

V. The Participation Of The Institute Of Automotive And Transport Engineering, ISAT, On These Competitions.

The Institute of Automotive and Transport Engineering (ISAT) in Nevers (France) is a state-run school committed to the comprehensive training of engineers, with a particular interest in the automotive sector.

The main aim of ISAT is to cover the whole range of jobs and skills related to the automotive and transport industries, with a strong expertise in mechanics: mechanical design and development, industrialisation, manufacturing, quality assurance.

Based on sound scientific and technological foundations, the training of the students during the 5-year programme (Master's Degree) is extended and strengthened by long periods of work experience and placements with various companies.

During the third year, as a part of the course's mandatory activities, the most of the students join in one of the four automotive competitions ISAT is taking part: Formula Student (Figure 4), Formula Baja (Figure 5), EcoShell Marathon (Figure 6) and Formula LowCost (Figure 7).

Each team is formed by 12 to 15 students that have to specialized into the different technologies involved. Although the schedule al ISAT is planned to work every Wednesday of the third year on these projects, the students used to employ many hours of their free time.

Figure 4. The Formula Student team at Magny Cours tracks

Figure 5. The Formula Baja team at the USA competition

Figure 6. The whole EcoShell Marathon team at ISAT

Figure 7. Some Formula LowCost members at the workshop.

All the work is supervised by teachers and workshop employees, but the students have a high level of autonomy and responsibility both in the technical areas as well as in the planning and budgeting activities.

Finally for INSIA-UPM and ISAT these projects represent opportunities to develop teaching programs, methods and activities oriented to improve the engineering education, with the special interest on the automotive industry.

VI. The Activities Performed At The Competitions And The Developing Of Personal And Professional Skills.

Although there are many differences between these competitions, all of them have in common the way the students do the work (with technical, schedule and budget requirements and constraints) and assume their responsibilities

On this point, it should be noticed that the responsibility given to each student is real: each is aware that a mistake by them is a mistake for the team. Equivalent responsibility would only be found in any company after a couple of years' work. The students themselves even take it upon themselves to raise part of the financial resources needed, and it is they, under the supervision of the teachers, who manage these resources.

The educational experience provided by taking part in these projects and the teaching methods used mean that the student must face up to specifically designed situations that will challenge them and promote their personal and professional skills. Table VI shows 16 different learning situations related to different moments or activities of the project, cross-referenced with 24 skills, which in the light of the literature consulted and the studies and surveys presented, are deemed to be the most sought after in an engineer getting ready to work in the automotive sector.

TABLE VI. PROMOTION OF PERSONAL AND PROFESSIONAL SKILLS ACCORDING TO DIFFERENT ACTIVITIES AND LEARNING SITUATIONS.

Learning situations / Skills	1. Initial training in all knowledge areas	2. Supplementary material and in-process tutorial sessions	3. Division into sub-groups according to work areas	4. Assigning duties, objectives and responsibilities.	5. Organisation and planning according to general costs and schedules	6. Every student is responsible for their work and collaborates with the others	7. Wide personal autonomy and possibilities for innovation	8. Periodic presentation and update meetings	9. Resources searches and usage management	10. All take part in vehicle manufacture	11. Former students coordinate activities of newcomers	12. Participation in a real experience	13. Putting acquired knowledge into practice	14. Competing against the world's best universities	15. Presenting and defending work done in front of a panel	16. Need to disseminate the experience and the results
1. Ability to work as part of a team			X	X	X	X		X	X	X	X	X		X	X	X
2. Leadership qualities			X	X	X	X		X	X	X	X	X		X	X	X
3. Ability to motivate			X	X	X	X		X		X	X	X		X	X	X
4. Capacity for responsibility and commitment		X	X	X	X	X	X	X	X	X	X	X		X	X	X
5. Capacity for innovation				X		X	X			X		X	X	X		
6. Negotiating skills			X	X	X	X	X	X	X	X	X	X		X	X	X
7. Capacity for self-motivation	X	X	X	X		X	X		X					X	X	
8. Analytical skills	X	X	X	X	X	X	X	X	X				X	X		
9. Ability to summarise				X	X	X	X			X		X	X	X	X	X
10. Capacity for criticism and self-criticism		X	X	X	X	X	X	X		X	X	X	X	X	X	X
11. Ability for self-learning	X	X	X	X			X						X	X		
12. Organisational and planning skills		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
13. Ability to identify problems			X	X	X	X	X	X	X	X	X	X	X	X	X	X
14. Ability to resolve conflicts				X	X	X		X	X	X	X	X	X		X	X
15. Ability to generate new ideas (creativity)				X		X	X	X	X			X	X	X	X	X
16. Ability to take up new initiatives				X	X	X	X		X	X		X	X	X		X
17. Ability to adapt to changing circumstances	X		X	X	X	X			X	X	X	X	X	X	X	X
18. Ability to work on one's own	X	X		X	X	X	X						X			
19. Ability to make decisions				X	X	X	X	X	X	X	X	X	X	X	X	X
20. Interpersonal skills			X	X	X	X		X	X	X	X	X		X	X	X
21. Ability to assimilate and apply knowledge	X	X		X		X	X			X	X	X	X		X	
22. Capacity for dynamism				X	X	X	X		X	X	X	X		X	X	X
23. Capacity for discipline and self-control	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
24. Oral and written communication in a second language	X	X							X			X		X	X	X

VII. ASSESSING THE EXPERIENCES

Right from the start of their own projects, both universities have been interested to know the opinion of the students taking part, what needs to be kept as it is, what needs improving, and obviously, to what extent the project's goals have been achieved. And among these goals is the distinguishing improvement in students' personal and professional skills compared to traditional activities.

At UPM, for instance, students taking part were given a survey with the 24 most important skills for an engineer in the automotive sector in order to get to know their opinion of the importance of these skills when working in their profession, as well as the level of their success in the subjects taken as part of their degree, and likewise during the Formula SAE training process.

Various conclusions can be drawn from the general results of the survey that are shown in Table VII:

- Students consider the most important skills to be a capacity for responsibility and commitment, teamwork, decision making, creativity, solving conflicts and communication in English. This classification is in total harmony with the opinion of companies, which shows that the training experience suitably orients students towards the labour market, especially if we compare the results with those shown in Table I.
- The average score given by students to the list of 24 skills is 4.2 points out of 5, their average level of success during their degree being given 2.3 points,

while achievement during the Formula SAE project is 3.6 points.

TABLE VII. SCORES FROM 0 TO 5 POINTS OF THE IMPORTANCE GIVEN BY STUDENTS TO THE 24 MOST IMPORTANT PERSONAL AND PROFESSIONAL SKILLS FOR AN ENGINEER IN THE AUTOMOTIVE SECTOR, AS WELL AS THE EXTENT OF SUCCESS DURING THEIR DEGREE AT THE SCHOOL OF INDUSTRIAL ENGINEERS (ETSII-UPM) AND DURING THEIR TIME ON THE PROJECT (F SAE).

Skills	Level of importance for students	Degree of success in ETSII	Degree of success in F SAE
1. Ability to work as part of a team	4.9	2.0	4.1
2. Leadership qualities	4.2	1.1	3.6
3. Ability to motivate	4.4	1.3	3.8
4. Capacity for responsibility and commitment	5.0	3.2	3.8
5. Ability to innovate	4.2	1.3	3.6
6. Negotiating skills	3.6	1.2	2.8
7. Capacity for self-motivation	4.0	2.2	3.2
8. Analytical skills	4.4	2.8	3.4
9. Ability to summarise	4.0	3.1	3.3
10. Capacity for criticism and self-criticism	4.0	2.1	3.6
11. Ability for self-learning	4.2	3.9	4.3
12. Organisational and planning skills	4.0	3.2	3.2
13. Ability to identify problems	4.8	2,6	4.0
14. Ability to resolve conflicts	4.4	1.9	3.3
15. Ability to generate new ideas (creativity)	4.4	1.3	3.6
16. Ability to take up new initiatives	3.7	1.3	3.3
17. Ability to adapt to changing circumstances	4.1	2.7	3.9
18. Ability to work on one's own	3.4	3.8	3.2
19. Ability to make decisions	4.9	2.0	4.0
20. Interpersonal skills	3.8	2.7	4.3
21. Ability to assimilate and apply knowledge	4.1	3.0	4.0
22. Capacity for dynamism	3.8	2.0	3.7
23. Capacity for discipline and self-control	3.8	3.0	3.3
24. Oral and written communication in a second language	4.4	1.6	3.1
Mean value	**4,2**	**2,3**	**3,6**

The average score of importance given to the 7 most appreciated skills is 4.7 points out of 5, with a score during their degree of 1.9 points and practically double, 3.7 points for the Formula SAE project.

Similar results are given by ISAT student's evaluations: the students taking part in the four competitions highly appreciate their own experiences as an important tool to improve the most important personal and professional skills appreciate by companies, more than other activities and experiences carried out during their studies.

VIII. CONCLUSIONS

In this work we have reflected on the growing importance being given by universities to the promotion of personal and professional skills, and the most important of them, on the opinion of the automotive sector, have been found out thanks to the Delphi questionnaire.

The automotive university competitions are very useful activities for the improvement of those desired skills. In the competitions analyzed both at the UPM and at ISAT, a whole set of learning situation is been planned for the students, as well as the methods and means to solve them.

At the end of the experience, students' valuation of the most important abilities and skills highly agree with the requirements of companies.

It has also been showed that the involvement of the students in the whole activities of four competitions, has more contributed to the improvement of the personal and professional abilities and skills than the rest of the activities done during the whole career of five years.

Despite of the good educational results, the advisory teachers have designed a new set of experiences to improve the useful and time profitably of our students.

Although this study has been exclusively referred to the automotive engineering sector, the methodology used and the principal conclusions can be applied to any other sector. Indeed, the 24 skills selected to evaluate the project do not specifically belong to automotive industry, but they are really appreciated by any other kind of industry. The fact of had asked the opinion of their professional served us only to prioritize them.

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MotionLab

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Abstract— **MotionLab is an experimental system for the study of physical motion created as a learning objective of the Industrial Engineering students. MotionLab uses the accelerometers and the infrared camera of a game controller as a data acquisition interface present in the consumer electronics market. The aim of this system is to monitor and to study the results of physical experiments about solids motion under different conditions. This research line, aimed primarily at education, tries to build low-cost experimentation systems replacing the classic ones, which result, mostly, as less efficient and need more expensive laboratories.**

Keywords-Laboratory experiences; remote laboratories; accelerometer; low cost; motion; sensor, physical experiments.

I. Introduction

Currently, consumer electronics offers better performance features every day, thanks to its large-scale manufacturing, which has produced a decrease in costs. Two of the technology sectors in which faster evolutions have been made are the telecommunications and entertainment sectors in which new products incorporate advanced technologies that traditionally had a high cost.

All over the world the process of technological change resulting from the Information and Communication Technologies (ICT) is causing significant changes in areas like economy, society, science and education, which substantially influence the patterns of production, organization and development.

Two factors have enabled this fact, using ICT as tools of development:

i) Lowering the costs of technological devices (laptops for under 200 €, better and cheaper communication, etc.)

ii) The emergence of new devices equipped with different sensors that allow the capture of environmental information (such as smart phones, game consoles like Wii, equipped with accelerometers, proximity sensors, video cameras, etc.) at lower prices every day.

Nowadays there is a great activity on this field which is called to represent a cornerstone of worldwide engineering education. The recent popularity of the remote laboratories concept and the existence of abundant bibliography prove its importance in the education area. These activities are focused on research areas like [1], which is oriented to microelectronic device characterization, or on learning and educational methods oriented, such as [2], [3] and [4].

One line of the research of the authors is the research of new low cost learning methods in education through remote labs and the simulation of physical experiences for students of Industrial Engineering. Some of the research lines about a low cost laboratory can be seen in [5].

For engineering students, laboratory and practices constitute a fundamental step in the learning process. Indeed, laboratory experiments help them to improve the understanding of concepts and skills, to familiarize with the use and management of measuring equipment and to develop specific skills required for future work. For these reasons, the most important institutions, which deal with scientific-technological training, try to dedicate a large budget to equipment and maintenance practices' laboratories. However, the evolution of technology quickly results in these equipments becoming obsolete and needing replacement, consequently increasing the investment in this educational activity.

With the emergence of the last generation entertainment systems, focusing on getting a great user experience, researchers and professionals that come from other different areas and which are motivated by this reduction in costs and by the easy reuse of components have began to consider these technologies for very different purposes from those that were originally conceived.

In this case, this research line is focused on the reuse of low-cost devices used in the new generation of video consoles, which incorporate technologically advanced control devices. These controls contain different types of sensors such as accelerometers, infrared cameras, gyroscopes, etc. The reuse of these devices has allowed the construction of MotionLab, a high precision experimental system oriented to the study of physical experiments, such as motion experiments.

Consumer electronic devices, that incorporate accelerometers, which can be used for different applications of those they were originally conceived, as it is the case of the Wii remote controller (called Wiimote) connected to other devices with greater capacity to process such as a PC, can be found in the market. In the educational field there are other researches using this remote controller like [6].

The study of physical motion, such as kinetic motion, is essential for engineering students. Students begin to explore concepts such as velocity and acceleration. For a correct understanding, in addition to the theoretical knowledge of these concepts, experimental study is essential for their comprehension as well as practical experimentation. One of the best ways to study acceleration and its effects is using accelerometers to accurately show the characteristics of a concrete experiment. In this laboratory it is shown that it isn't necessary to use high accuracy sensors, and therefore high cost, but low-cost sensors that can perform these experiments and that allow to students acquire a high grade of assimilation of the theory.

In particular an experiment has been built consisting on the study of the movement of a mobile object in an incline plane.

As it will be described later, this is an ongoing project in which the first prototype has just been completed and although it has been tested in laboratory, it hasn't been used by students yet. The first tests will be done in this course (2009-10).

The structure of the paper is as follows. In section II, the system concept is reviewed. In Section III, one experiment as a concrete use case is described. Section IV shows the advantages of the system. Section V explains the experimental results. Finally, section VI draws some conclusions.

II. Description

A low cost laboratory is not just a set of applications that captures several physical data, but must meet certain requirements.

First, students must have in the same application a manual with the theoretical foundations, operating principles and objectives clearly and accurately expressed (operating manual, practice script, etc.).

So all the experiments that have been developed in this laboratory are not limited to programming and assembling of a device, (hardware and software), but require a careful design where certain educational requirements, besides the technical requirements, are taken into account.

User experience is another key factor and therefore the application should be handled easily, with an intuitive user interface. Students should focus mainly on the experiment design and the application has to let them do it.

In addition, it is really important to test the application, under conditions of normal use, with a sufficient number of subjects, and to make an evaluation of the results and to change everything which needs to be changed. Obviously the implementation of this process requires a multidisciplinary team consisting of software developers and teachers of the subject concerned.

The main objective and the origin of this system was to obtain a low-cost universal platform for studying the motion of solids in different conditions. As mentioned, MotionLab is a system for the study of kinetic experiments that allows the study of solids motion in different conditions (collisions, pendulum-like motion, etc.). As a fundamental element, the system uses the Wii remote control device (manufactured by Nintendo and available on the Wii console) and the built-in sensors. It is a flexible and scalable system that enables rapid incorporation of new types of experiments.

A remarkable effort has been made in the MotionLab design making an open and extensible development which enables its expansion and the incorporation of new sensors in the most simple and transparent way.

A web application complements MotionLab which allows students to share and to store the results of the experiments. It also allows teachers or administrators to manage the system.

A. Architecture

Different approaches [7] can be used in order to design the architecture of the system. Two approximations have been chosen, the first one a low-level controller, which is in charge of controlling all the equipment, and the second one a web based subsystem. Relevant technical aspects in this approximation are explained in this section.

Following, a general architecture of the system is showed:

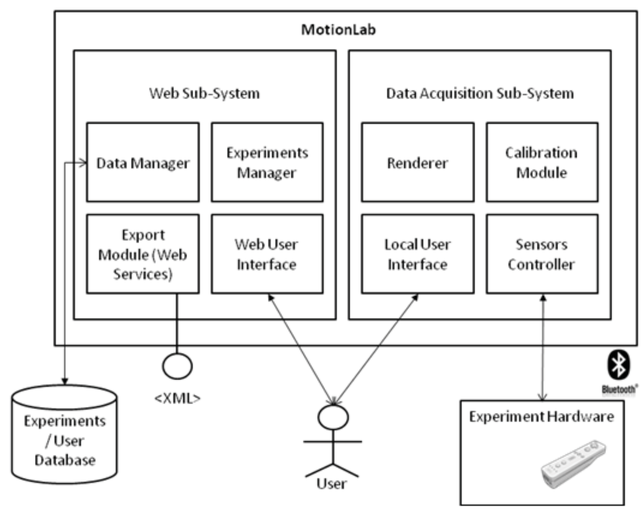

Figure 1. MotionLab Platform

As seen in Figure 1. , there are two main parts, the "Data Acquisition Sub-System" and the "Web Sub-System".

The first one is in charge of the acquisition and the data renderization, i.e. this sub-system controls the experiment hardware, calibrates the system, obtains data and then it makes the renderization process in order to represent it to the user through the local user interface.

a) The data acquisition sub-system manages and coordinates the modules of this sub-system and communicates with users through the local interface in order to receive orders and display information.

b) The graphics module is responsible for representing all information of the samples, sensors and application experiments. It draws and displays all the data in real time on the screen.

c) The Sensor Controller is the responsible of the communication with the experiment hardware and its sensors. It makes the connection with the Wiimote control and it receives data from its sensors in order to transmit them to the data acquisition sub-system.

The second one is in charge of the experiment management and the data exportation to third party systems, i.e. this sub-system manages all the experiments, user profiles, manages the experiment and the user database and exports the experiences to other systems using web services. Users can review the experiences and manage profiles using a Web user interface.

a) The data manager module is responsible of managing the system data at real time and to make them persistent. The database stores MotionLab projects, created from the web application and it can manage user permissions and projects stored in it. In addition, it can export experiment data to any physical storage medium.

b) Publications in the web site are done using web services, and all structured data are sent in XML format. Using web services enables to develop platform independent applications, making the system accessible for third parties (using a "Universal Description, Discovery and Integration" directory, UDDI).

c) Communication with other third party systems can be done through the "Export Module". It uses Web Services with structured data in XML. The use of standards of this technology provides extensibility and transparency.

d) This communication feature enables teachers from other locations to use all of the experimental data to their specific needs, without having their own laboratory.

Finally, .NET platform has been used for the system implementation as development environment, for both, data acquisition sub-system and web sub-system. Visual Studio 9.0 and C # development language have been used and for data persistence the database manager MySQL 5.0 has been used.

B. *Wiimote*

As mentioned before, Wiimote is the video game controller device developed by Nintendo for the Wii console. This remote control can be used for the development of positioning systems and it is a low cost device with a great performance.

Wiimote has three accelerometers, i.e. an instrument for measuring acceleration, detecting and measuring vibrations. The accelerometer built-in Wiimote is the ADXL330, a chip MEMS (micro electro-mechanical system) made by Analog Devices. This device is capable of measuring both acceleration and direction movement or rotation in three axes. Basically, the accelerometer operation is based on a piece of silicon, held to an end, and placed between the electric field exerted by two capacitors.

ADXL330 [8] is a small, thin and low voltage chip, which is composed of three accelerometers, one for each axis with variable voltage signal output. The device measures acceleration with a range of ± 3 g. It can measure the static acceleration of gravity in applications that require monitoring of tilt, as well as dynamic acceleration resulting from motion, shock, or vibration. The output signals are voltages that are proportional to the acceleration detected by the accelerometer. It offers an acceptable performance for the project and provides the following features: three axis sensors, small and thin potting (4 mm × 4 mm × 1.45 mm), low consumption. (200 uA to 2.0 V), a single point of supply (from 2.0 V to 3.6 V), shock tolerance 10,000 g and an excellent stability against temperature. It also contains a MOT (Multi-Object Tracking) sensor (engine vibration), a Bluetooth chip and a connection port for peripherals.

Silicon is in charge of transmitting the movement, when the Wiimote is moved, the silicon bar is closer to one of the capacitors, which makes the electric field changes, this change is detected and real-time translated into a motion. In Figure 2. , a Wiimote sketch can be observed.

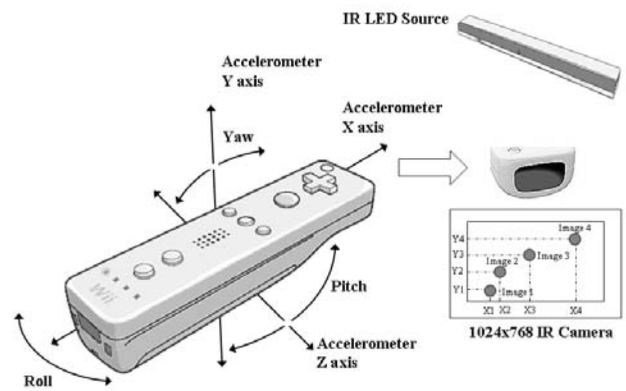

Figure 2. Wiimote

In the front of the Wiimote there is a translucent dark plastic, and behind it, it is placed the MOT infrared sensor made by Pixart Imaging. This sensor visually keeps tracks of multiple objects with a resolution of one megapixel. So to run, it needs an infrared source, consisting in this case of several LEDs arranged in a bar.

The Wiimote's sensor locates these LEDs, forming the ends of a "virtual display" that will be the relative action field. The computer screen acts, in this case, as a display.

To work properly the application must be set up, indicating the position of the bar and the aspect ratio of the display screen (16:9 or 4:3). In this way, the remote is able to continuously "know" its position in space and its accelerations in the x, y and z axis.

All data, motion detection and position are sent directly to the Broadcom Bluetooth chip (built in the remote). In addition, these data are sent from this chip to the computer's Bluetooth adapter where they are stored as well as real-time shown in the display. The recorded file can be exported in Microsoft Excel format in order to be treated (as for instance to represent the positions and accelerations of the studied solid).

III. Experimental Case

A. Types of Experiences

The experience object to study is the uniformly accelerated one-dimensional motion of a mobile in an incline plane. This is done on a leaky aluminium pneumatic rail connected to an air pump so that the mobile object is moved on an air mattress. This air mattress hugely reduces the friction.

The experiment allows students to get practical knowledge about the following three aspects of kinematics and dynamics of one-dimensional motion:

1) Uniform Motion (UM). As shown in the equations (1), (2) and (3) is characterized by a linear dependence of distance over time: so the velocity is constant and there is zero acceleration. On the mobile object any force is working.

$$v = constant \quad (1)$$

$$a = 0 \quad (2)$$

$$x(t) = x_0 + vt \quad (3)$$

To make this experience, a fork is placed on each side of the mobile object. The uniform motion is accomplished by pressing the cradle of the mobile object against the top of the rail and leaving it free.

In the experiment the graphs (4) and (5) are displayed.

$$x = f(t) \quad (4)$$

$$v = f(t) \quad (5)$$

2) Uniformly Accelerated Motion (UAM). The equation which calculates the position is (8), the velocity is (7) and the acceleration is constant (6) as it correspond to a constant force.

$$a = constant \quad (6)$$

$$v(t) = v_0 + at \quad (7)$$

$$x(t) = x_0 + v_0 t + \frac{1}{2}at^2 \quad (8)$$

This type of motion is achieved by tilting the rail. A flat piece of known thickness is placed under one leg (the supporting one) of the rail. Knowing the angle of inclination of the mobile, the mass and the acceleration obtained from experience, allows the students to verify the validity of the second law of Newton.

In the experiment the graphs (9) and (10) are displayed.

$$x = f(t) \quad (9)$$

$$v = f(t) \quad (10)$$

3) Collisions. The interest in this experiment is checking the law of conservation of linear momentum (11) and to distinguish whether the collision is elastic or inelastic taking into account the variation of kinetic energy, E_k.

$$p = m\,v \quad (11)$$

Two types of shock can be accomplished:

a) Elastic collision, it is achieved by putting two accessories in the ends of the mobile objects that will collide, a fork in the first one and an elastic accessory plate in the other one.

b) Perfectly inelastic collision, the two mobile after the collision must remain joined.

In the experiment the graphs (12), (13) and (14) are displayed.

$$x = f(t) \quad (12)$$

$$v = f(t) \quad (13)$$

$$E_k = f(t) \quad (14)$$

B. Prototype

Next figures (Figure 3. and Figure 4.) show two photographs of the prototype based on the platform MotionLab. In this case, MotionLab is being used as a data capture system for a low friction air rail. The pneumatic rail is an experiment that can be considered classic, which studies the kinematics and dynamics of solids in one dimension. The usual data acquisition devices for this experiment consist of a series of photoelectric cells, usually two, which besides being quite expensive only allows obtaining data in only two points of the track.

The pneumatic rail experiment consists of the following parts:

1) A pneumatic rail made of a square aluminium tube (63 mm x 63 mm), 2 m long, supported on three legs that allow levelling. It presents a series of holes through which pressurized air goes out, forming a pneumatic bed between the rail and the mobile object which minimizes friction. The air stream is supplied by a blower pump connected to the rail by a flexible hose.

2) Rail made of anodized aluminium, l = 130 mm, which can incorporate several elements.

3) Pluggable screen made of plastic, mountable on the rail to stop the rays of light from the photoelectric door. (L = 35 mm). This element is used in the classic experience and enables to obtain comparisons between MotionLab and the classic one.

A huge advantage of MotionLab is the data acquisition in a continuous way.

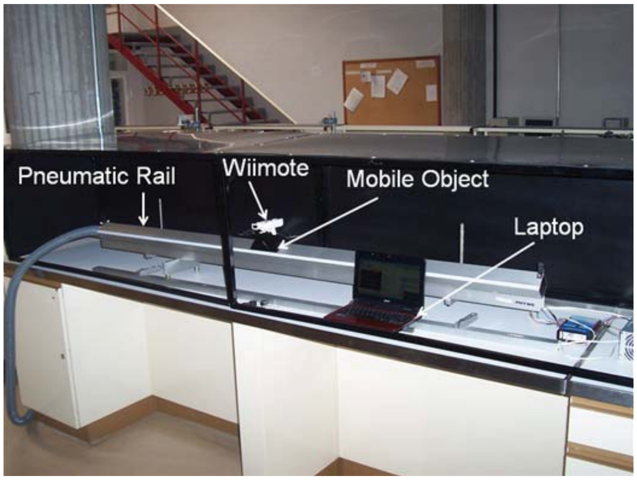

Figure 3. Prototype I

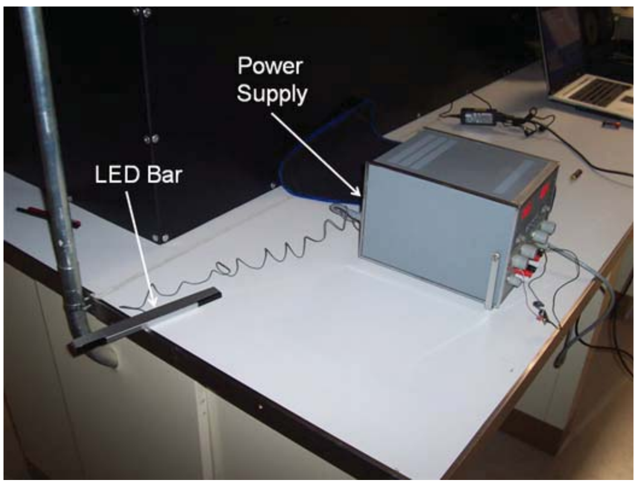

Figure 4. Prototype II

As shown in Figure 3. the experimental assembly basically consists of:

1) A Wii remote control (Wiimote), equipped with its corresponding sensors and placed on the mobile whose motion is being studied,

2) A computer (an ultraportable with a built-in Bluetooth adapter or a laptop perfectly suits the performance needs) and an infrared diode bar parallel located to the air rail and spaced about 1.5 m out (Figure 4. left).

C. Working with MotionLab

1) Getting samples

When a new sample is created, different options of calibration are possible, depending on the type of the selected experiment. Figure 5. shows the basic structure of the sample panel:

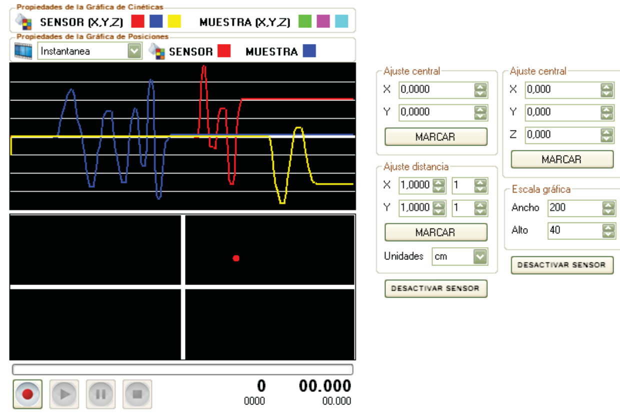

Figure 5. MotionLab Acquisition Application

In this panel, three elements can be seen:

a) Representation charts: in the top left, one or several charts represent real-time values obtained from the sensors.

b) Calibration panels: on the right of the charts, there are different options to configure and calibrate the sensor involved in the experiment.

c) Recording and playback panel: underneath the charts, the necessary buttons for recording and playback data from a sample can be found.

Before recording a sample, sensors must be calibrated. Depending on the sensor used, its placement and the characteristics of the physical experiment, parameters must be adjusted in different ways. MotionLab offers several automatic calibration tools to facilitate these tasks.

Once the sensor has been calibrated, the application is ready to record data obtained by each sensor, the procedure is the same for any of them. To start recording, simply press the record button. When the experiment is finished, users must just press it again to complete the data collection.

2) Configuring Experiments

To obtain an experiment is the main goal of MotionLab. An experiment consists of one or more samples combination. Once selected the samples of the experiment, students will configure them in order to have the experiment ready for analysis.

When students are working with an experiment, they can find, depending on the type of experiment, different charts and options. Figure 6. shows an experiment and all parts which it is composited (different samples, etc.).

Figure 6. Experiment

The main element is the centre panel where the samples selected for the experiment are rendered simultaneously. On the right, the list of experiment samples and the panel to configure them can be found. At the bottom the experiment playback buttons, its duration and some other controls are placed.

3) Exporting Experiments Data

With an already configured experiment, MotionLab offers several options to export data in different formats. This is an easy procedure in which both the experiment and the output data format is needed to select.

In the website all reports that students have published can be searched through the publication service. Then, all associated report data can be seen.

Next figures show some parts of the web sub-system, specifically Figure 7. shows the report management application. As show in the figure a form to enter search criteria is used to search experiments reports. It is possible to search by title of the experiment or by the author name. When the search is finished, all results contained in the specified text are listed. Each report has the author's name, a title report and date of execution as metadata.

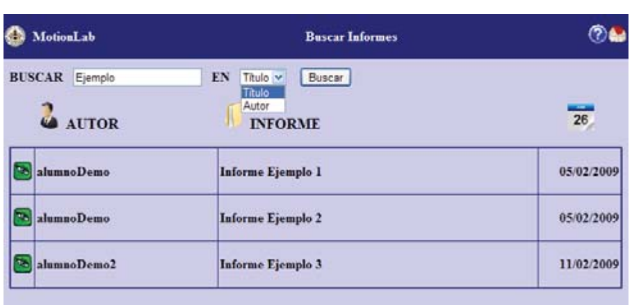

Figure 7. Report Management Application

In Figure 8. a report detail is shown as an example. All data that the report contains is displayed to the user.

Figure 8. Report Detail

Students who have published their reports can manage them using their credentials. They are able to view or delete them from the system using the web application. Only the owner or an administrator can manage them.

IV. ADVANTAGES OF MOTIONLAB

MotionLab provides significant advantages over the traditional experimentation systems. On the one hand, it substantially improves the cost per experiment, e.g. in some experiments a special paper is used for trajectories visualization in which the paper is literally "burned" by the moving object. This means a significant saving in cost per experiment and in cost per student.

TABLE I. shows a brief cost comparison between MotionLab and the classic laboratory:

TABLE I. COST COMPARISON

Modality	Cost	
	Element	***Total***
MotionLab	Wiimote, LED Bar, Power Supply	60 €
Classic	Equipment (photoelectric cells, etc.)	600 €

It also provides a greater cooperation among students and a higher apprenticeship allowing making comparisons among experiments of different groups of students which results in a higher quality education.

More advantages of this system are the following ones:

a) One of the most important advantages is that it is a very didactic system which enables the understanding of the experiment by the student far more quickly than with traditional systems.

b) Remote access. In order to allow students to conduct experiments from anywhere at any time, and remote controlling parameters of the experiment.

c) It is technologically advanced and the lab equipment has a better performance and it is available to students more time.

d) Distance courses. MotionLab allows the organization of engineering courses.

e) Autonomous learning. MotionLab promotes autonomous work, fundamental in the European Higher Education Space.

f) Furthermore these tools foster independent learning, as advocated by one of the main guidelines of the Bologna system marked by adaptation to ECTS (European Credit Transfer System).

g) Cool factor, wiimote has a very cool factor which is very important to encourage and motivate students in the learning process. Moreover, due to the fact that for engineering students laboratory and practices constitute a fundamental step in the learning process this is an aspect to take in account.

V. RESULTS

As shown in Figure 9. two experiments can be seen in the same graph. Both of them are plotted in two different inclinations of the plane. In the figure the curves with circles are those of the classic experiment using photoelectric cells while the curves with squares correspond to the experiment using MotionLab.

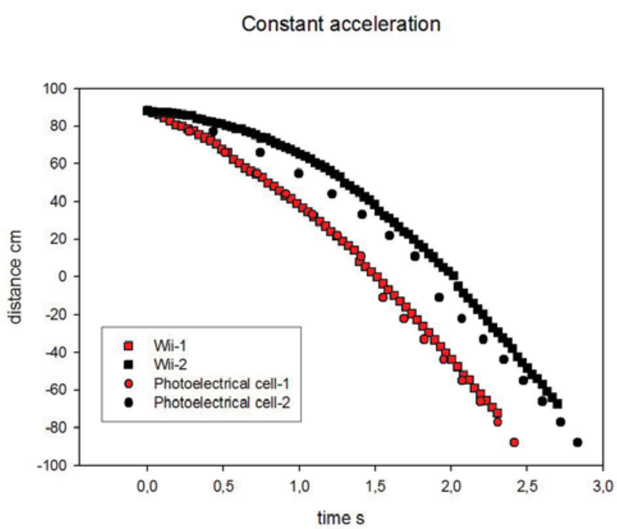

Figure 9. Comparison between MotionLab and the Classic Experience

As mentioned there are two graphs one of which shows the experience using MotionLab while the second one shows the results using the traditional experience with the photoelectric cell system that has the classic rail.

As it can be seen the experimental results are quite similar. But while the classic experience provides a smaller amount of data (limited to the number of photoelectrical cells), with the use of MotionLab a greater number of points are obtained, which enables to obtain more accurate results and closer to the theoretical model.

VI. CONCLUSION

The application of low cost sensors in building some real kinetic experiments have been presented. This is a low cost data acquisition system for physical experiments using the three-axis accelerometers and the infrared camera built in the Wiimote. The system has been used for experimentation of uniform motion, uniformly accelerated motion and several kinds of collision.

The results are really good according with the expected results. The system allows graphic visualization of the experiment and can be used to perform a wide number of experiments, for instance it can be used in all types of pendulums, simple, physical, coupled pendulums, springs... and generally in any experiment which involves motion.

This prototype has just been completed and although it has been tested in laboratory, it hasn't been used by students yet. The first tests will be done in this course (2009-10) and they will start soon.

Making real experiments, it has been found that the possibilities of the system would be increased if multiple sensors of the same type were simultaneously working. For instance, in some kinds of collision is really interesting to study the trajectories of multiple mobile objects in order to obtain a more complete experience.

Therefore, the addition of several Wiimotes is proposed as a future expansion to provide more functionality to the system. In fact, right now a new platform is starting to be developed and it will bring major improvements, like for instance including the ability to work with up to eight remote controls and incorporating a new more sensitive sensor (that Nintendo has just released last summer).

This second version is being developed using the LabVIEW graphical programming language instead .NET platform (it has been used in the prototype described in this paper). Nowadays using LabVIEW is a good option for remote laboratories and it has been used by some prestigious entities around the world [9] with good results.

The most remarkable thing of this work it is a low cost experience and quite easily applicable in any laboratory or educational institution that may be interested.

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Reflections about Teaching Engineering Graphics: Knowledge and Competencies Management

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Abstract— **This article contains some reflections about the experience of the authors after a decade teaching assignments within Engineering Graphics area, like Graphical Expression, Computer-Aided Design, Industrial Drawing, Descriptive Geometry and Technical Drawing, and others related to several Master Programs as Master in Graphical Design. Reflections consider advantages and disadvantages of those traditional experiences regarding to graphical aspects, such as the magisterial Class, practical classes in small groups or working out different tasks and how all of this affects the final results, considering students opinion.**

On the other hand of this traditional system is another one based on the learning directed to those students who have ECTS credits, inside the European Educational Higher Space (EEHS) and the experiences in several Universities before entering 2010-2011 season. Knowledge and competencies management are considered within this new system and they be included in the Teacher Guide so that those students who approve the subject acquires specific competences (subject specific knowledge). These competencies coordinated with those specific obligates teachers to develop particular activities, because the detailed knowledge of each is a main condition in order to program competencies briefings with a high detail level. This is not an easy task considering the experiences and opinions of famous professionals specialized in competences issues.

Therefore, new activities should be set up and include new Information and Communication Technologies, such as Internet, search of information, E-learning educational platforms, and a different orientation for individual and group follow up and for seminars and classes in the University environment as well. Sometimes, practical orientation of the lesson should focuses on real cases, on the solution of a real problem. This is more complicated in lessons during the first year when there is a lack of knowledge of other subjects considering that a lesson is not a knowledge "island" in a "sea" of subjects. Nevertheless, besides the difficulties those teachers who have not got that specific training have it becomes a closer challenge and a push to enter the EEHS with a renewed motivation and a different vision about new activities that should be develop.

Keywords- Engineering education; Engineering drawings

I. INTRODUCTION

Knowledge and competencies management [1] within Engineering Graphics subject [2] has been analyzed from different points of view several times, but only a few times it has been analyzed from transversal competencies related to the design of specific records for its evaluation.

University education considered inside the Europe an Educational Higher Space (EEHS), not only pretends to reach of professional competencies in order to get updated knowledge, technology and specific abilities and be in touch with the real professional world but also to make students acquire knowledge about modern languages, about how to use TICs, how to be creative and keep training constantly, be adaptable to job market, get abilities for teamwork, verbal and written expression and have critical spirit.

According to EEHS one goal of the learning process is the acquiring certain kind of knowledge and developing some transversal competencies according to each one's own academic profile and its correspondent professional profile.

There are basically two kinds of competencies: Specific (technology), related to technical knowledge and Transversal (general), not necessary related to technical knowledge.

Specific competencies are mainly based on the contents of subjects included in the program of the course and that fulfil those requirements described in BOE (Spanish Official Bulletin). Moreover, transversal competencies are generic and should be established in the degree and normally programmed for the subject.

Thus, for designing and evaluating competencies is necessary to know the content of the subject precisely in order to elaborate appropriate records for each one. [3].

II. PRACTICAL APPLICATION

Until a couple of years ago competencies treated in Teacher Guide were basically contents. Since the mandatory implementation of Degrees, as part of the adaptation process to EEHS, Teacher Guide should include activities in order to make students acquire some transversal competences.

As mentioned before, it is not about designing activities to evaluate all that competencies but those considered more appropriate for the subject. Table 1 shows some transversal competencies that can be included in Teacher Guide [3].

As an example, we take a main subject for getting the Engineering Degree in almost all universities, Engineering

Graphics. It has 6 ECTS credits (European Credit Transfer System) and it's also a common subject for several degrees during the first year.

The pilot experience of implantation of ECTS is being applied for some years and Engineering Graphics subject began to be taught 4 years ago. Definitive implantation will not take placed until next period (2010-2011), so this experience applied in the University of Jaén, is helpful to get as good Teaching Program.

Particularly, this subject has 6 credits in the ancient system (4'8 ECTS) and its content includes: Descriptive Geometry, Spatial Conception, Normalization and Industrial Design Basements and is taught in one hour of theory and 3 of practice per week.

Main goals of the subject are:

- To develop spatial conception and abstract thinking.
- To manage technical drawing elements and instruments, set up formats, scales and others.
- To dominate normalization and criteria applied to technical drawing and be able to understand and elaborate one.
- To work in group and use Engineering Graphics resources to share technical information.
- To be able to represent pieces and groups of Engineering Applications using representation systems.
- To be able to deduce and apply principles of Industrial Design in technical graphics.

TABLE I. TRANSVERSAL COMPETENCES

Nº	Transversal Competence
1	Planning and managing time
2	Verbal and written Communication
3	Using TIC
4	Managing Information (search, selection and integration)
5	Solving problems
6	Taking decisions
7	Critical thinking
8	Teamwork
9	Abilities for personal relations
10	Consciousnes of ethical values
11	Ability to put knowledge in practice
12	Autonomic Learning
13	Ability to adapt to new situations
14	Creativity and innovation
15	Responsability
16	Selfconfidence
17	Initiative and enterprising spirit

The experience of programming a Teacher Guide mentioned above has been applied in developing and evaluating (from 1 to 10) different activities as following:

- Practical final exam: max 7 points
- Constant evaluation of practices: max 1 point
- Doing and presenting mandatory group work: max 0.5 points
- Doing and extra exercise of increasing difficulty: max 0.5 points.
- Assistance to group tutorials, journeys, seminaries: max 0.5 points.
- Related information search through Internet: max 0.5 points.

As described before, exam has a quote of 70% of the final qualification and the rest 30% are activities in and outside the class.

Competences in Table 1 are related to each activity as following:

- Practical Final Exam (1-5-7-11).
- Constant Evaluation of practices (1-4-5-11-12-15-16).
- Doing and presenting mandatory group work (1-2-3-4-5-6-8-9-10-11-15-17).
- Doing and extra exercise of increasing difficulty (1-4-5-7-11-12-15-16).
- Assistance to group tutorials, journeys, seminaries (2-6-9-10-13-15).
- Related Information search through internet (1-3-4-6-13- 15).

But designing activities in order to get certain competencies is not always easy and depends on the nature of the subject. We honestly think this serial of activities reinforce an important amount of transversal competences explained before.

There are other examples of transversal competences much more detailed [3] that include 4 items as following:

1. **Competence Nomination**
2. **Definition of the Competence**: Definition, description, competences needed to develop this one and other competences developed from this one.
3. **Develop of the Competence:** Training activities used to develop it.
4. **Evaluation of the Competence**: Concrete and simple items used for the evaluation and its process, such as observation, interrogation or performance; evaluation instruments related to process; and bibliography.

Nevertheless, from a practical point of view it is better to develop a work report as following that includes the development of activities in a specific teaching week. Although only a practical session along a week is explained as an exam ple of aut onomic work rep ort, i t shoul d be a pplied during all weeks along 4 months.

3rd Week from October 19th to October 23rd 2009:
DIEDRIC SYSTEM I

Transversal Competences:

- Ability for putting knowledge into practice.
- Information m anagement (search, sel ection an d integration)

Specific Competences:

- To t rain for the c orrect representation of n otable elements (do t, straigh t line, p lane) and related position between each other in the Diedric System.

Objective:

- To dominate criteria and norms of Die dric Syste m (Representation System) applied to Technical Draw.
- Search Basic and c omplementary bi ographical information.

Content:

- 2nd Theme. Diedric System
  - Chapter 1: Nota ble ele ments. Representation.
  - Chapter 2 : Relative p osition between notable elements.

Development activity:

- Description: E laboration of a 4 exe rcises practice. Tiempo: 3 hours.
- Resources, bibliography and spaces:

Resources nee ded a re E uclidian tools (set square a nd triangle, millimeter ruler, compass, triangle, angle carrier, 2H hardness pencil and eraser as well). Besides, it is also required t he PDF document containing the exe rcises for the practice a nd locate d i n the file platform of t he university of Jaen.

Basic an d com plementary b ibliography is listed in th e Teacher Guide of the subject.

Practices will take place in room 31, building A4 in Las Lagunillas Cam pus, p rovided with projector, bo ard an d drawing tables.

Evaluation Criteria:

- Presential assistance to practice.
- Clean and draw.
- Correct result.

Nevertheless, one of the most complicated parts is how to evaluate learning pr ocess. B esides teacher evaluation o ther evaluation tools should be established, such as self evaluation, equal e valuation a nd co-evaluation between teache r and student.

There are se veral technol ogy [4, 5] that evaluate t he learning of facts and issues such as opinion polls, conce ptual maps, self v aluation and equ al ev aluation or th e learn ing of procedures (control lists, estima tive scales and polls); a nd the learning of attitudes, such as a nalysis of speech and productions.

Proposed e valuation t ools c ould be i mproved f or s ure i n order to get mo re clarity in t he process, but th e d iversity of evaluation too ls and th e lack o f tim e make it h ard to fi nd a valid result.

III. Final Reflections

We can list following final conclusions:

1. Designing activ ities in o rder to g et certain competences is not easy and depends on the nature of the subject.
2. Designing sp ecific and developed re port for transversal com petences is complicated at the very beginning due to a lack in teacher training. They are prepared i n their professi onal area but in most case s they do not know the pedagogic basements and other issues related to teaching innovation.
3. Recommending teacher training i n activities about learning evaluation considering that the output of that process can i mprove t he resul ts seri ously. B esides, making the student participate in the evaluation of its own learning process make it possible to detect weak points and reinforce the strong ones.
4. Establishing a national net of Teacher Guide that include recommendations about how to elaborate this text because although each professor ca n freely program the s ubject, the mix of expe riences from other professors from many Spanish Universities, is a more rich source to consult.

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Measuring collaboration and creativity skills through rubrics

Experience from UTPL Collaborative Social Networks Course

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Abstract—**In this paper, we introduce several rubrics to measure a set of collaborative and creativity grading. Rubrics are powerful tools for both teaching - learning and assessment. Rubrics improve communication between teachers and students. This work relates the general criteria to measure the complexity levels in the development of creativity and collaborative work competences with concrete indicators associated with the use of Social Web tools and concepts. These indicators have been used in the assessment of competences in a particular course related with the use of collaborative networks.**

Keywords-component, Rubrics, Social Software, Assessment

I. Introduction

Engineer employers affirm that some competences in certain non-technical areas such as communication ability, economics, leadership, teamwork or creativity are not practically being considered in their formation. Accreditation Boards, Engineering Associations, are also demanding the incorporation of the called generic or transferable competences for the actual and the future engineering degrees. Generic competences constitute the basis for the ability to develop discipline-specific competences. At present, faculty and staff are developing and articulating these important linkages to create strong curricula plans. Firstly, it is needed to define competency mapping as the process of identifying key competences for a particular degree. This process involves supporting and enabling staff to fully reflect upon potential competences, conducting formal research to identify the most important competences, and reaching consensus. Finally, this approach supposed important changes in the current teaching-learning processes of many Institutions.

Key competences should be acquired by pass from a hierarchic model (where teachers are considered as knowledge dispensers), descendent and focused on the teachers toward a collaborative model/horizontal where the student is in the centre of the model and teachers fulfill their role of guides in the teaching - learning process. These key competences are all interdependent, and the uses of social web tools are potential facilitators of that change, especially with the creativity and collaborative work competences.

Creativity is considered as the ability to provide novel answers to a proposal or problem given, or to discover new relations and give them new mental structures, respectively. Rubrics are evaluation instruments that can be applied to assess these competences. But they require the identification of new indicators that can be directly assessed. This work relates the general criteria to measure the complexity levels in the development of this competence with concrete indicators associated with the use of Social Web tools and concepts. These indicators have been used in the assessment of competences in a particular course related with the use of collaborative networks.

II. Benefits of Rubrics Assessment

Rubric assessment of competences and skills results in a number of benefits to students and teachers in Universities [1,2,3].

Rubrics allow students to understand the expectations of their instructors. They provide direct feedback to students about what they have learned and what they have yet to learn. Second, students can use rubrics for self-evaluation. Finally, rubrics emphasize "understanding rather than memorization, 'deep' learning rather than 'surface' learning" [5].

Teachers also can benefit from rubric assessment in two important ways [6]. First, the rubric creation process provides an opportunity to discuss and determine agreed upon values of student learning. Rubrics "make public key criteria that students can use in developing, revising, and judging their own work". They also noted that once rubrics are developed, they could be used to norm teacher expectations and bring them in line with the vision for student learning.

Second, rubric assessment offers university manager and faculty assessment data full of rich description that can be used to document how to improve courses. Rubrics provide "detailed descriptions of what is being learned and what is not" [11].

"Rubrics improve communication between teachers and students," said *Andi Stix*, an educational consultant whose book *A Rubrics Bank for Teachers* will be published by Teacher

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Created Materials. Stix noted that rubrics help students understand exactly "what is expected of them when they are writing a paper or designing a project.

Rubrics can be deceptively difficult to write. After carefully developing a rubric, it is worthwhile to test it on five or ten samples of student work to see how the rubric works.

III. Rubrics For Evaluating Collaborative Social Networks Course

Today we see an enormous use of Web 2.0 / Social Software tools and services outside the educational sector. A stronger use in the educational sector could have a considerable impact in terms of changes in educational practices. UTPL understands the necessity of shift towards practices that promote learner-centered as well as collaborative approaches. Social Software tools allow for easy publishing and sharing of ideas, content, experiences, opinions and links (“user-generated content”).

The developed of skills and competences for the knowledge society require decisive shift away from teacher-centered knowledge-transfer: a) students: active, constructive and collaborative engagement of students – as close as possible to “real world” problems, content and expertise, b) teachers: facilitators of learning processes – requires change in educational culture/mind-set and new professional understanding

Social Software or Web 2.0 provides a new window of opportunity for initiatives with focus on developing competences and skills for the knowledge society. Blogosphere and Wikipedia, has made possible that any person can participate actively in the society of knowledge. Social software allow collaborative filtering, discovery of “most interesting” web resources through social filtering techniques, also through ongoing conversations, recommendations and cross-linking of resources in social networks Weblogs, Wikis, content and bookmarks sharing, social networking, etc.

A. *Defining Criteria for Evaluation of Student Performance*

The purpose of use Web 2.0 in education is considerer the benefits from the collective intelligence, the positive effects of networks, and collaborative tasks through Internet. Specifically: Tools where every participant had the opportunity to participate in the elaboration, publications, consult, provision, improvement, and debugging of its contents.

Three rubrics based on Bloom’s learning taxonomy [4,8] (knowledge, comprehension, application, analysis, synthesis, and evaluation) were created to evaluate the students’ activities on the co-curricular activities of Social Web [13], *rubrics for evaluate wiki editing, blogging and social bookmarking*.

The use of social web wiki, blogs and social bookmarking enhanced learning, with these social tools, the knowledge is viewed as a social construct, facilitated by peer interaction, evaluation and cooperation.

B. *Rubrics for assessment wiki editing*

This is a rubric for the wiki editing, see table I. Wiki is a collaborative environment. Collaborative environments allow using tools for co-authoring and debating. The use of wikis is a good example of transition from static and restricted web to social and collaborative participation (co-authors). The wikis enable to create, modify, and delete content in collaborative way.

TABLE I. RUBRICS FOR WIKI EDITING

Dimension (rubric criteria)	**Levels of performance**			
	Poor	**Regular**	**Good**	**Very good**
Intellectual Engagement with Key Concepts.	The wiki pages make no reference to issues and key concepts raised through readings and/or module activities.	The wiki pages make some reference to issues and key concepts raised through readings and/or module activities.	The wiki pages demonstrate awareness of most of the key concepts raised through readings and/or module activities.	The wiki pages demonstrate engagement with the important concepts raised through readings and/or module activities.
Structure, spelling and grammatical errors	The wiki pages have poor spelling and grammatical errors.	The wiki pages have some spelling and grammatical errors. Text entered with limited enhancements	The wiki pages have few spelling and grammatical errors. Text is enhanced.	Spelling and grammatical errors are rare. The wiki pages have structure and are formatted and enhanced to increase readability.
Content and Understanding	The wiki pages are superficials, lacks of insight and depth.	The wiki pages show some insight and depth, and are some connected with topics and activities. The wiki pages attempts to address the learning objectives pages	The wiki pages show insight and depth are connected with topics and activities. The wiki pages address the learning objectives pages.	The wiki pages are relevants and show a high level of understanding and knowledge. The wiki pages clearly address the learning objectives pages.
Creative construction	Show no ability to incorporate creativity techniques throughout the wiki project. The content of wiki pages don’t meet the basic requirements of the wiki project. No creativity shown. Content has no imagination or surprises, is lacking information or is not creative.	Participants show some ability to incorporate creativity techniques during the wiki project with occasionally demonstrating awareness. Participant has created exactly what was required of him or her and nothing more.	Participants show a good ability to incorporate creativity techniques throughout most of the project.	Participants show a high ability of incorporate creativity throughout the wiki project. Content is filled with surprises and creativity. The content of wiki pages show that participant was thinking outside of the box - going beyond what participant would normally create. (Thinking differently or from a new perspective).

Wiki facilitates collaboration and sharing and enables the development of shared resources in a controllable environment. Mistakes are solved by social correction and with the support of content configuration management (version control).

Performance Criteria:

- Intellectual engagement with key concepts.
- Structure, spelling and grammatical errors
- Content and Understanding
- Creative construction

C. Rubrics for assessment Blogging

This is a rubric for Blogging, see table II. From an educational perspective, the blogging is autonomous, constructive and inherently conversational. Teachers or students can create a blog individually or in groups, they form their ideas about specific topics, gather, evaluate and interpret data and information, they assume positions, train in elaboration of arguments and evidence, and acquire abilities to express their thinking in the right way and style. Blogging allow creating, evaluating, analyzing, applying and understanding knowledge.

Rubric performance criteria:

- Intellectual engagement with key concepts;
- Structure, spelling and grammatical errors
- Linkage and cohesion among posts and use of external resources
- Timeliness and replies comments
- Understanding
- Creative construction

TABLE II. RUBRICS FOR BLOGGING

Dimension (rubric criteria)	**Levels of performance**			
	Poor	**Regular**	**Good**	**Very good**
Intellectual Engagement with Key Concepts.	The blog entries make no reference to issues and key concepts raised through readings and/or module activities. No comments are made on blogs of others participants.	The blog entries make some reference to issues and key concepts raised through readings and/or module activities. Comments have been made on blogs of others participants.	The blog entries demonstrate awareness of most of the key concepts raised through readings and/or module activities. Comments have been submited, though not all of them may give evidence of a substantial contribution.	The blog entries demonstrate engagement with the important concepts raised through readings and/or module activities. Blog includes many reflections. Comments have been submited, all of which are substantial contribution.
Structure, spelling and grammatical errors	The posts and opinions are short and irrelevants. The entries have poor spelling and contain grammatical errors. The entries lacks of structure and connection with topics and activities.	The posts and opinion are short and may contain some irrelevant information. Some of the entries have poor spelling and contain grammatical errors. The entries have some structure	The posts and opinions are expressed in an appropiate style and entries show a good depth of undestanding. There are few spelling and grammatical errors. The posts have structure.	The posts and opinions are expressed in an appropiate style and are connected with topics and activities. The entries have rare spelling and grammatical errors. The posts have structure and are formatted to enhance readeability.
Linkage and cohesion among posts and use of external resources	The posts don't have linkage and cohesion among themselves. The entries don't contain external links.	The posts have some linkage and cohesion among themselves. The entries may contain links to external digital resources.	The posts have linkage and cohesion among themselves. The entries contain links/images referred within posts.	The posts have linkage and cohesion among themselves. Each external link is referenced.
Timeliness and replies comments	The blog entries are irregular, tipically 1 to 2 for month	The blog entries have some timeliness. Some comments are replied to.	The blog entries are regular. Most comments are replied to in a timely manner. The reply shows understanding.	The blog entries are regular and timely. The replies show a depth of understanding and relationship to the comments.
Understanding	The posts are superficials, lacks of insight and depth. They don't express opinion clearly and show little understanding.	The posts show some insight and depth. The post have some connection with other topics and course activities.	The post shows insight and depth. The posts are connected with topics and course activities .	The blog entries are relevants and show a high level of understanding and knowledge. The posts show insight, depth and understanding, and are connected with topics and activities.
Creative construction	Show no ability to incorporate creativity techniques throughout the blog. The content of entries don't meet the basic requirements of the project. No creativity shown. Content has no imagination or surprises, is lacking information or is not creative.	Participants show some ability to incorporate creativity techniques during the project with occasionally demonstrating awareness. Participant has created exactly what was required of him or her and nothing more.	Participants show a good ability to incorporate creativity techniques throughout most of the project.	Participants show a high ability of incorporate creativity throughout the wiki project. Content is filled with surprises and creativity. The content of wiki pages show that participant was thinking outside of the box - going beyond what participant would normally create. (Think differently or from a new perspective).

D. *Rubrics for assessment Bookmarking*

This is a rubric for the Social Bookmarking, see table III. This is examining the process of recording and remembering key sites and URL's.

Delicious is a social bookmarking service that allows users to tag, save, manage and share web pages from a centralized source. With emphasis on the power of the community, Delicious greatly improves how people discover, remember and share on the Internet.

Instead of having different bookmarks on every computer, Delicious makes it easy to have a single set of bookmarks kept in sync between all of your computers.

Performance criteria:

- Storage and organization of bookmarks
- Tagging and comments
- Collaboration and relevance of bookmarks

TABLE III. RUBRICS FOR SOCIAL BOOKMARKING

Dimension (rubric criteria)	Levels of performance			
	Poor	**Regular**	**Good**	**Very good**
Storage and organization of bookmarks	Bookmarks are locally stored, lack of structure or organisation.	Participant add site favorites to Browser. Bookmarks are organised into folders with appropriate name.	Participant add web sites to a social bookmarking service (i.e. del.icio.us).	Favorites web sites are add to a social bookmarking service (i.e. del.icio.us).
Tagging and comments	Participant does not add tags or comments to bookmarks.	Participant sometimes adds either tags and/or comments.	Participant adds tags and/or comments. Tags are mostly well constructed.	Participant adds appropiate tags and/or detailed comments. Comments summaries the resource.
Collaborations and Relevance of bookmarks	Participant rarely shows any cooperation during the course. Exhibited little to no positive attitude. The bookmarks are personals.	Participant shows some level of cooperation throughout parts of the course. Occasionally exhibited a positive attitude. The bookmarks are irrelevants and don't be validates.	Participant showes a good level of cooperation throughout most of the course. Usually, maintaining a high level of commitment to a positive attitude. The bookmarks have some importance and exist attempts of validation. The student shares the bookmark with all members of their network.	Participant shows an very good level of cooperation throughout the entire course maintaining a high level of commitment to a positive attitude. The sites are bookmarked on the basis of relevance and validity. The student shares the bookmark with appropiate members of their network.

IV. RUBRICS APPLICATION

A. *Context Of Application*

Competences and learning outcomes have acquired renewed relevance for the *Universidad Tecnica Particular de Loja* (UTPL) process of curricular reform. UTPL are considered a key aspect for answering to the fast technological change in the Knowledge society and to the gap between the education and the labor market requirements. Although learning outcomes are concepts very used in United States and some European countries (United Kingdom, Denmark, Finland, France), in the Ecuador case they are in the early stages of developing and planning.

For UTPL, inspired in Bologna process, the official degrees will have to provide a higher education formation in which the generic competences are integrated harmonically with basic ones; transversal competences related to the integral formation of the student and specific competences than make possible a professional profile that allows the graduates integration in the work market.

The rubric discussed in this paper, was used within Computer Science School offered the Collaborative Social Networks Course (CSNC) as an elective course in 2008-2009. Collaboration and creativity are 21st Century competences of increasing importance and that are used throughout the learning process. CSNC has the following modules: blogs, wikis, RSS, social networking, and social tagging.

Course enrollment a total of 214 students and four tutors experts in Web 2.0 tools and evaluation in higher education. Given their practice nature, all modules were organized to assist students in their development and mastery of social software tools and services.

B. *Purpose of study*

This course explores the use of social software technologies as channels of conversation (and information) as well as how web 2.0's underlying principles change the way people communicate and interact in the knowledge society. Of particular interest in this study is how university students use social software to generate collaborative intelligence with partners, engage in discussion (and debate) and how they use tools to deliver innovative services.

The study objective is assessing and crediting the results of CSNC based at collaborative activities before and after.

Because rubrics are easy to use and to explain, they generate data that are easy to understand, defend, and convey [12].

/

C. Process

The first step in designing a rubric was to define the criteria that will be used to evaluate the assignment activities of participation and use of Social Web tools and services [7,9]. CSNC teachers have considered the assignment carefully and determine which aspects of the modules (Wiki editing, blogging and social bookmarking) should be evaluated. The second step was test rubrics with samples of student work to see how the rubric works.

The third step was to record academic performance prior to rubrics. The four step was to make public key criteria that students can use in developing and self-assess their work. Then, apply rubrics, record academic after rubrics and then provide those who have been assessed with clear information about how well they performed your work.

D. Performance levels

Making a rubric takes time in our case several days. Coming up with criteria and descriptors for a final product or assignment takes detailed thinking on what the product should like. Then, a teacher needs to think of what poor, regular, good and very good quality work should look like to conform to the university approved grading scale:

By making teachers expectations clear, rubrics make rankings, ratings, and grades more meaningful [10]. In this specific context, the performance levels, or anchors, are labeled:

- 0 - Absent—component is missing
- 1 - Poor, unsatisfactory: needs significant improvement
- 2 - Regular, somewhat satisfactory: needs targeted improvements
- 3 - Good, satisfactory: discretionary improvement needed
- 4 - Very good, very satisfactory: no improvement needed

The criteria are: Structure spelling and grammatical errors, linkage/cohesion among entries, use of external resources, timeliness, creativity, collaboration, understanding, scope, accuracy, coherence, and depth. These criteria are commonly applied to social web tools, as are other attributes such as clarity, rigor, appeal, and strength of argument.

E. Application of Rubrics for wiki editing

The procedures followed in this study can be divided into four parts. First, the teachers prepared the artifacts of student learning and study materials (modules: wiki editing, blogging, social bookmarking). Then, the students were trained in CSNC contents - without they know about rubrics score - its performance was evaluated and the results were registered. Third, students participated in training about scoring rubrics session, then, UTPL faculty evaluators scored and returned students works. Finally, the score sheets were prepared for statistical analysis. At the close of the study, all evaluators returned their rubric score sheets. The rubric score sheets were organized for data entry and analysis (see table IV).

Data for Table IV:

- Participant's number: 214
- Faculty evaluators: 4
- Quantity of wiki pages revised (*without rubrics*): 428 (two contributions per participant)
- Quantity of wiki pages revised (*with rubrics*): 428 (two contributions per participant)

The table IV shows academic performance before rubrics and academic performance after rubrics. We estimate the location of the statistical mode, the accumulate percentage in order to determine the number of students who shows academic performance above and below the Good category.

TABLE IV. TABULATION - RUBRICS FOR WIKI EDITIG

Dimension	Before/after rubrics	Very good	Good	Regular	Poor	Mode in category:
Intellectual Engagement with Key Concepts.	Without rubrics	34	137	**197**	60	Regular
	Accumulated	8%	40%	86%	100%	
	With rubrics	90	**175**	141	21	Good
	Accumulated	21%	62%	95%	100%	
	Variation	56	39	-56	-39	
Structure, spelling and grammatical errors	Without rubrics	30	141	**210**	47	Regular
	Accumulated	7%	40%	89%	100%	
	With rubrics	64	**197**	154	13	Good
	Accumulated	15%	61%	97%	100%	
	Variation	34	56	-56	-34	
Content and Understanding	Without rubrics	39	146	**193**	51	Regular
	Accumulated	9%	43%	88%	100%	
	With rubrics	120	**158**	133	17	Good
	Accumulated	28%	65%	96%	100%	
	Variation	81	13	-60	-34	
Creative contruction	Without rubrics	26	94	**223**	86	Regular
	Accumulated	6%	28%	80%	100%	
	With rubrics	47	137	**201**	43	Regular
	Accumulated	11%	43%	90%	100%	
	Variation	21	43	-21	-43	
	Mean without rubrics	**32**	**129**	**205**	**61**	**Regular**
	% Accumulated	8%	38%	86%	100%	
	Mean with rubrics	**80**	**167**	**157**	**24**	**Good**
	% Accumulated	19%	58%	95%	100%	
	Variation in means	48	37	-48	-37	

The right column of Table IV shows the statistical mode, the mode is the value that occurs the most frequently in the each rubric dimension. Before rubrics, the statistical mode is located in the *Regular* performance level. After rubrics the statistical mode shifts to the *Good* grading scale. The benefits of rubrics far outweigh the time and effort that goes into them. They force us to carefully consider what we are doing in the classroom, how that leads to student achievement of our course, program, and university, and how we will know when students have achieved those outcomes.

On average, without using rubrics the 39% of students (83 persons) have a good and very good performance at wiki editing. With rubrics there is an improvement in performance, in this case 58% of participants (124 people) is located in the range of good and very good performance.

F. Advantages of using rubrics in CSNC

According to the tables IV, the advantages of using rubrics in CSNC assessment are that they:

- Allow assessment to be reasonably more objective and consistent from activity to activity and from student to student, especially in our situations that involve collaboration among four teachers.
- The level of detail found in three rubrics: wiki editing, blogging and social bookmarking helps prevent inaccurate, clearly show the student how their work was evaluated and what was expected.
- Three rubrics promoted student awareness of about the criteria to use in assessing peer performance. In addition, provide useful feedback regarding the effectiveness of the instruction.
- Focus to our teachers to clarify his/her criteria in specific terms. Because rubrics clarify schemes for assessment ahead of time, they reduce subjectivity in grading.
- The rubrics provide benchmarks against which to measure and document progress.

V. Conclusions

Teachers and students exhibit a level of proficiency in the use of rubrics, this study demonstrates that teaching of Web 2.0 tools may be empowered through evaluation based on rubrics.

CSNC Teachers appreciate rubrics because their "accordion" nature allows them to accommodate heterogeneous social tools:

- With Rubrics, the writing from blogging and wiki editing is clear, concise, and easy to understand. Ideas and responses are communicated clearly and coherently. Timeliness, the responses are submitted on or before the due date.
- Rubrics reduce the amount of time teachers spend evaluating student work. Rubrics provide CSNC students with more informative feedback about their strengths and areas in need of improvement.
- Integration and synthesis of concepts and principles: The blogging and wiki editing responses demonstrate an integration of concepts and principals from classroom discussions and reflect an understanding of fundamental principles.

Critical Thinking: The interaction through of Web 2.0 tools demonstrate use of upper level thinking, analysis, synthesis, and evaluation and illustrate a thoughtful approach to the content.

Acknowledgment

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Challenges in an Emerging Country: A Digital Divide Case Using Robotics
Barone, Dante Augusto Couto; Gomes, Marcelo Carboni; Horwath, Karla Chagas
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Challenges in an Emerging Country: A Digital Divide Case Using Robotics

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***Abstract*— This digital divide case is sponsored by UNESCO and Brazilian Education Ministry as a pilot-project science and technology democratization initiative named RoboEdu. The main role is to allow that high school students can be the first technologies contacts using computers and robotics experiments due them low profile families remuneration. The initiative uses education interactions as main engine to guarantee the math and physics studies understanding and to reach the best cognitives practices approaching to the ideal pedagogic model. The teacher needs technical support also cause the language used must be translate to a simple vocabulary where students achieve the learning goals. The educator essential role starts to be several possibilities of knowledge generation not mattering anymore who knows technologies but through the part of the involved ones into orientation, participation and exchange of experiences. When the teachers and students are engaged on these activities pertaining to school evasion is reduced drastically**

Keywords-component: digital divide; robotics; technologies; educational learning

I. INTRODUCTION

This article describes the development of the activities under the RoboEdu project, which allows students from the public network to have their first contact with computers and robots, interacting during classes of Math and Physics, that deal with subjects from the practical experiments, in a more curious and questioning manner formatter will need to create these components, incorporating the applicable criteria that follow.

The use of tools that allow the improvement of the topics addressed by the educators is a key factor on the quality of learning at the schools. Educational, or Pedagogic, Robotics, is a strategy of exposure of the knowledge and takes the practice of the individual, by fixing issues by assembling and adapting equipments and models that shall present moves, such as robots.

This learning environment is characterized by the use of robotic systems, which allow students to build systems composed by a physical part (hardware), that constitutes the robot's structure, and programs (software) that sets the interaction of the knowledge acquired at the classroom and their behavior.

In this context, suggestions of unconventional learning present themselves for students and teachers of the public institutions, from practice to theory and from theory to practice, showing gaps of knowledge not explored until then, and, moreover, it allows these students that, many times, are poor, both socially and economically, the contact with state of the art technology, that ends up allowing curiosity and knowledge to act as stimulants.

II. JUSTIFICATION

In this pilot project, the learning stimulus focus on the involvement of the students in the activities related to studies performed in the classroom, applied through the simulation of throws in a basketball game, using the KickRobot software, and handling and controlling of robots physically composed, before their pairs or classmates, generating, this way, a more effective participation of the involved with a focus on the best work resulting of a team performance.

According to Resnick, when a person is committed into building something that is significant to the person itself, or to the people around, the building of knowledge happens in a more effective way. When the student is involved in building and modeling robots, this student starts to have a greater sense of care in the relation with this object, different than it would be if the student had received the robot already assembled. In this manner, the students are prone to explore and make deep connections with scientific concepts based on the activities performed [1].

Under the scope of digital divide it is necessary, besides making teachers and students familiar with the technologies of robots and computers, give support on the aspects related with the language or way of communicating this topics, the method employed during the demonstration of assembling, modeling and proper use of the different tools (hardware) involved and a proper environment to learning, among other social and cultural aspects, that intertwine the daily life of students with low income.

III. DIGITAL DIVIDE

The exclusion is mainly through the environment in which they socialize. The barriers may be present many difficulties such as access to technology, or a basic premise, the food. If the body is not nourished, strong and tuned barriers become insurmountable. Arises the need to help the company to break the problems encountered and form a virtuous cycle with a focus on social and digital divide.

The inclusion can not simply access to equipment or technology, but support for the formation of citizen and professional opportunities that will climb in the labor market. According to Paulo Freire [2], the inclusion should enable the inclusion of individuals with critical historical process, and create conditions for people to master the subject contents, the educational process must allow people to become aware of their potential, to become autonomous and able to free themselves from oppression in order to decide and choose - education should be a liberating action.

These activities have the potential to become the mind works, that is, showing how a person thinks, performs an activity and includes the realization of that done. Profits are able to go forward, learning and continuous production of new artefatos.A digital inclusion can then be identified when the individual is recognized as someone who will be able, who can believe in yourself, that is, increased self-esteem through the use of information technology and communications.

IV. EDUCATIONAL ROBOTICS

Educational robotics, or pedagogic robotics, is being used as a learning tool that allows the development of activities as stimulation tool to the creativity of students, due to the dynamic, interactive and even playful nature, further on, it serves as a motivator on the concern of students about traditional education.

Robotics have a great deal of potential as an interdisciplinary tool, seeing that the construction of a new mechanism, or the solution of a new problem, frequently exceed the classroom [3]. In the natural attempt of searching for a solution, the student questions the teachers of other disciplines that may help finding the best way for the solution of the problem [4].

Robotics, then, take the role of the bridge that makes possible the restoration or boarders previously established, acting as an element of cohesion within the curriculum. According to Simões, [5] the main pedagogic advantages of robotics are:

- It transforms learning in to something motivating, making principles of Science and Technology accessible to students;
- It allows testing on physical equipments what was learned using model programs that simulate the real world;
- It helps overcoming limits of communication, allowing the student to vocalize the knowledge and experiences, developing the capacity to argue;
- It develops the reasoning and logic in the construction of algorithms and programs to control mechanisms;
- It favors the interdisciplinary interaction, promoting integration of concepts from areas such as: math, physics, electronics, mechanic and architecture.

V. LEARNING ENVIRONMENT

During the development of this pilot project we tried to insert precepts that are named by UNESCO's Jacques Delors Report, a study recommended by the United Nations, as the four pillars of education. This study gathered the main features of the 21st century worker, with grounds on globalization and technological advances, and, furthermore, it has an observation on the need of development of the values and competencies of the students.

Mainly, in what connects to the pillars, it is applied on the project:

- Learning to learn: where we exploit the awakening of the pleasure of knowing, comprehending, discovering, building and rebuilding knowledge, having curiosity;
- Learning to do: developing competencies and abilities that bring about the application of technology in modern life;
- Learning to be: taking the student to the development of new logics and creativity, whole development of personality through self esteem, self determination, self realization and personal sensibility;
- Learning to live together: aspects that show the comprehension and respect to values and culture, developing the perception of interdependency, capacity of administrating conflicts and appreciation of people.

The proposed environment of learning is based on the application of the knowledge acquired by the students and supported by the teachers of the disciplines of math and physics through the use of educative robotics for practical measurement of the topics developed in class.

The proposed environment is based on the implementation of a competition of pedagogic robots using the software developed and named KickRobot.

VI. KICKROBOT

The KickRobot application is based on the competition among students that use pedagogic robots on an adapted competition of basketball. This competition focuses on the throw (kick) of balls at a virtual hoop, where the motto is the application of mathematical theorems and physics' formulas to achieve the goal, converting the throws in to points (Figure 1).

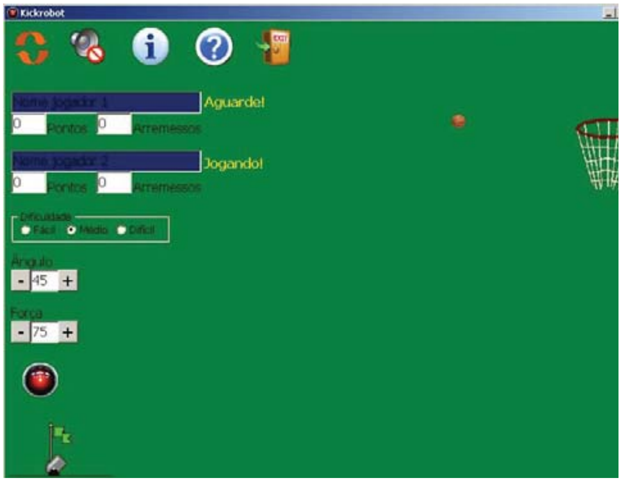

Figure 1. Basketball Court used in the KickRobot application

All the scores from the participants are registered and the five bets scorers will have their names registered at the gallery of players, what will promote the clash among students (Figure 2).

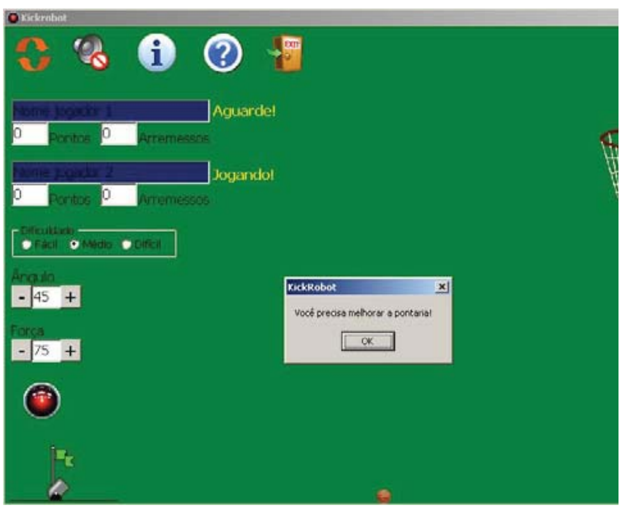

Figure 2. Cannon from the KickRobot application

The throws will be based on studies involving vectors, mechanics and trigonometry, and will be performed by the pedagogic robots in cannon format (Figure 3).

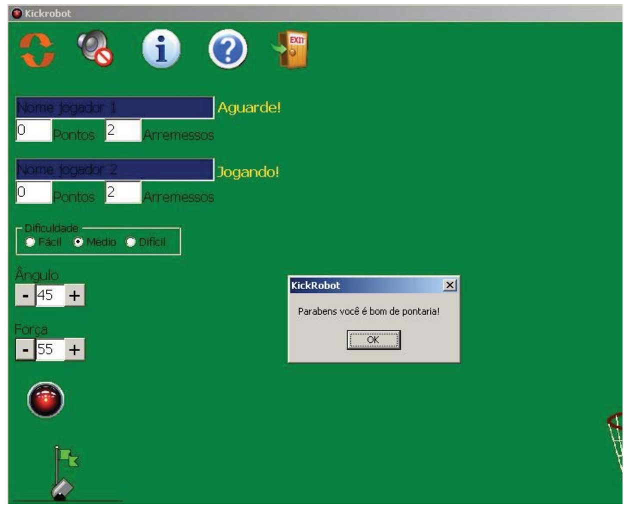

Figure 3. Hit of the "target"

So that it is possible to perform a precise throw, it is necessary to establish values based on the physical and mathematical experiment that used premises that involve concepts of projectile throws, vector analysis of movement, trajectory equations and parabolas (Figure 4 and 5).

Figure 4. Online Help

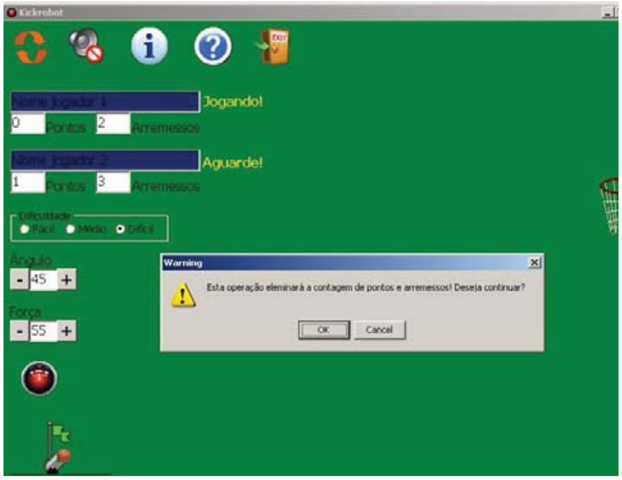

Figure 5. Finalization or Game Restart

VII. Physical-Mathematical Experiment

The principal of the involved study implemented refers to the theory of projectiles. At the implementation formulas applied on shooting allow us to observe the behavior of the projectiles on real experiments.

A projectile is an object that suffers an strength at a determined period of time, that we may call impulse. This impulse causes a variation of the target that we are willing to hit. One of the forces directly involved with the impulse is gravity.

At the experiment we will perform the throw to a target not on the same level; this way, settings will have to be applied. Principles that were developed originally out of Brazil, namely the measuring system that uses feet, instead of meters. Therefore, acceleration in the English system is $g=32.2$ ft/s², converting to the metric system we have $g=9,8$ m/s².

The movement performed by the ball is bi-dimensional and can be analyzed separately as two simple movements, one going horizontal (axis X) and other going vertical (axis Y).

From the movements, we have the formulas for the speed (Figure 6):

$$\vec{v} = \vec{v}_0 + \vec{a}t$$

E posição:

$$\vec{r} = \vec{r}_0 + \vec{v}_0 t + \frac{1}{2}\vec{a}t^2$$

Onde:

$\vec{v} = v_x\hat{i} + v_y\hat{j}$ velocidade;

$\vec{v}_0 = v_{0x}\hat{i} + v_{0y}\hat{j}$ velocidade inicial;

$\vec{r} = x\hat{i} + y\hat{j}$ posição;

$\vec{r}_0 = x_0\hat{i} + y_0\hat{j}$ posição inicial;

$\vec{a} = a_x\hat{i} + a_y\hat{j}$ aceleração.

Figure 6. Formulas used by the KickRobot software

Writing the bi-dimensional movement as two one-dimensional movements will give us, for the horizontal direction (X) and for the vertical direction (Y), the following equations for speed and angular position (Figure 7):

$$x = x_0 + v_{0x}t$$
$$y = y_0 + v_{0y}t - \frac{1}{2}gt^2$$

Figure 7. Formulas used on the axis X and Y by the KickRobot software

This way, the student must notice that there is a direct relation between the initial speed and the maximum distance that the ball can reach according to the amount of speed indicated, as we see in Figure 8.

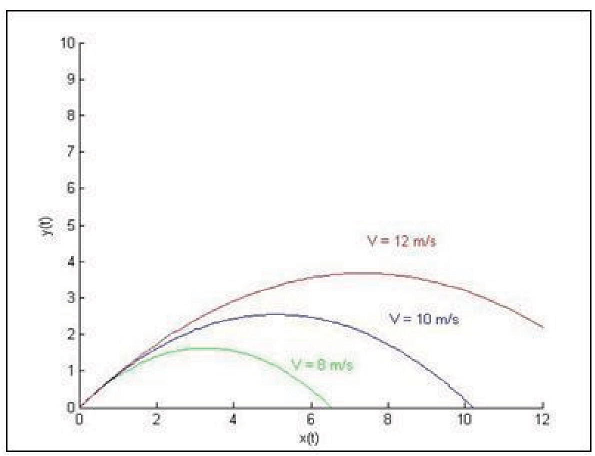

Figure 8. Trajectories with distinct speeds applied on KickRobot

Moreover, the student will notice a straight correspondence between the initial angle and the maximum distance that the ball might reach, related to the value of angle discovered during the experiment, as seen in Figure 9.

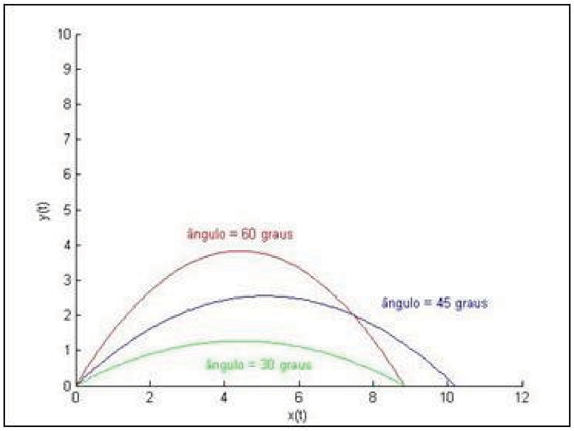

Figure 9. Trajectories with diferent angles applied in KickRobot

VIII. ROBOT SOCCER

The soccer competition among robots uses interconnected devices, working together, allowing the student-players to control their hardware tools. The used devices are: a camera, located on over the field, that captures image and sends it to the computer, where the computer will recognize the ball and all the robots, locating them within the field (Figure 10).

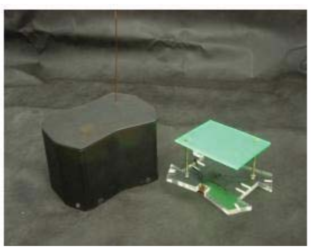
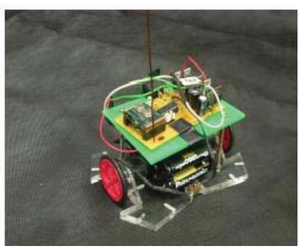

Figure 10. Robots used by the students to play soccer

An artificial inteligence algorithm receives this location and processes the game plan to be employed. After this, the movement coordinates are sent to the robot via radio frequency (RF). Following that, the robots interpret and execute the orders. This way, so that the system is really efficient, advanced techniques on computing, electronics and robotics are used (Figure 11).


Figure 11. Equipments used on the soccer match, with interaction with the students

IX. CONCLUSION

Through this article, the aim is to present a vision, both, macro and general of the pilot project named RoboEdu and the use of the KickRobot software on the aspects of digital divide and improvement of the knowledge acquired in the classroom. This is one of the first initiatives to spread the technology as a whole throughout the public network, but, mostly, under the scope of computers science on education supported by experiments with robotics.

Two public schools received the initiative, with a total of 50 students selected to take part on the experiments. Initial questionnaires were applied to outline the style of learning of the participants and knowledge about the technologies. The same questionnaires were applied at the end of the project.

After a relative evaluation on the gain of knowledge on technologies by the students, comparing the questionnaires, it's possible to conclude that the objectives were reached, on the aspects of technology, constructivism, and of social and digital inclusion. Around 25% of the students that started this project, identified by the questionnaires as shy students went on to take active part in the group of students that worked effectively and integrated within the teams.

Regarding the teachers involved, they obtained the same stimuli to develop the studies in the classroom, given the tasks defined focusing on the practice overlooking the experiments, that being said, we can say that the initiative contemplated not only students, but also teachers, that, during informal conversations, said that the activities had given them a new found interest for research and compilation of extra-curricular content, that were not a part of the daily activities.

This initiative doesn't end, it's funded continuously, aiming at covering as much students as possible with the experiments in question.

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Team Teaching for Web Enhanced Control Systems Education of Undergraduate Students

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Abstract— **The present work focuses on the didactic approach for the HE in technical-scientific domains, namely Control Systems undergraduate courses, via blended e-learning. Material knowledge has to be learnt. So, tools to be integrated in Moodle to manage related didactic variables have been developed, such as an Immersive Telelaboratory. In such a context a team approach to teaching was adopted. It seems useful to summarize such experience putting into evidence its potential and some critical aspects related to the implementation of the approach.**

Team Teaching, Material Knowledge, Immersive Telelaboratory, e-Learning

I. Introduction

Engineering designer education involves training students to master complex physical phenomena, to acquire competence in the analysis of complex systems in several application domains and to become able to develop proper design processes. The focus should be on acquiring the competencies and abilities of an expert designer. One among them is "Material Knowledge" (MK).

According to [1] Material Knowledge is the Knowledge relative to the real operation conditions of engineering complex systems. Mains features of MK are: its owners are experts; it is compiled and implicit, and can be described as intuitive; it is empirical, i.e. the novice has to learn more "how to do" than "what it is". To try to teach MK asks for active, experiential and collaborative learning in a supervised way.

For such purpose laboratory activities are practiced Face to Face (F2F), with a limited number of students. In traditional laboratories (as part of institutional courses at the University) students have the possibility to practice real or realistic experiences under teachers' and tutors' guide. In this way they can match the theoretical aspects learnt during the lectures and practical experiences.

To build, to maintain, and to use such labs is difficult, sometimes even impossible for organization problems, and it is always expensive. A didactic laboratory is a costly installation exposed to a concentrated use at certain times of the year. The need arises of guaranteeing the access to existing labs for a wide student's population, surely wider than the users present on each laboratory site. This need is apparent both at a local level – more students belonging to the same University - and, in principle, at a University system level - students belonging to different Universities could use laboratory settings not available at their own University on a reciprocity base [2].

For these reasons, having many students that could profit of it at our University, an Immersive Telelaboratory (IT) accessible by the net is used.

Immersivity is specified as follows: remote users experience the operation within the real environment – a laboratory – by means of a rich perceptive Internet-based bi-directional interaction comprehending vision, hearing, and perception of current modification of physical quantities [3]. No haptic interfaces are required.

Compared to an experience of Virtual Reality (VR) [3], Immersive Telelaboratory allows being in touch with MK. In general terms VR is a technology that allows a user to interact with a computer-synthesized environment, be it a representation of the real or of an imaginary world, and in every case it is based on a model. It is exactly for this latter character that these solutions don't provide the richness of experiential elements implicit in a real laboratory practice, related to the acquisition of MK. The immersive experience of the laboratory, even if based on a didactic approach with some simplifications, involves the elimination of the significant simplifications intrinsic to the VR model.

The laboratory experience is scaffolded in a context of training and gradual activities (Tutorial, process analysis, clarification of the issue of control), comprehending documentation and reflection on the experience performed.

To try to verify in an empirical study the previous statements, an undergraduate Control Systems course has been given following a Team Teaching approach (TTa). According to [4] usually TTa involves a team of teachers, each devoted to different tasks, in synchronous/asynchronous blended learning. In our case it has been used in a F2F/online blended modality. The focus is on pooling different competences more than on reducing the cognitive workload of the teachers. This second objective appears to be prevailing in asynchronous/ synchronous blended learning.

II. Eucational Design of the Course

We refer to an undergraduate course of Automatic Control, compulsory for an Information Engineering curriculum, having many students (around 300), delivered in blended e-Learning.

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Blended means a suitable mix of F2F lectures/numerical case-study presentation and on-line activities both tutored and untutored.

A. The Syllabus

In order to promote an active and collaborative learning an online course was devised. The course design required the definition of a detailed Syllabus. Main components of the Syllabus are:

Aim: the course will provide students with fundamentals of the theory and techniques of analysis and design of linear time invariant control systems single input single output. The control is usually feedback control.

Theory and techniques deal with a particularization of the Theory of Linear Dynamical Systems. In comparison with the international approaches to engineers training this course corresponds to courses named Linear Control Systems or Feedback Control of Dynamical Systems.

Learning Objectives: at the end of the course the student is expected to be able to explain to others the declarative knowledge learned in a clearly and compelling way and to apply operational skills in a competent way.

Course Description: the learning materials are learning objects (LO), which are collected in self-contained learning units (LU). A LU covers a topic autonomous from the didactic point of view, even if logically related to several others. In order to enable learning, the course also suggests many activities to be conducted alone or in small groups. All activities are always meant to take advantage from the discussion Forum where students, teachers and tutors are in touch.

Learning Objects (LOs): three kinds of LOs were developed.

1 Learning Objects related to declarative knowledge.

Declarative knowledge of the course is composed by definitions, conditions and theorems. These elements are available as downloadable documents that can be printed and studied offline. These documents are presented by synthetic introductory web pages.

2 Learning Objects that provide operational abilities. Learning operational skills is based on a number of examples and exercises, some of which are completely carried out and/or solved and others have to be played by the student. For this purpose, an Open-Source package SW – SCILAB™ - is made available and downloadable [5]. This package allows performing the calculations necessary to deal with a realistic example without facing with paper and pencil large sized computational problems, which would require a high amount of time and would be easily exposed to the risk of calculation errors.

The discussion of examples of this type is always preceded by exercises of limited computational complexity, which can be tackled with pencil and paper. Each student is asked to solve them and to post the solution on the forum. The review of these exercises is done by an online tutor. The tutor timely sends comments to help students to understand the reason for errors.

Each student is asked to address the more complex examples only if he/she has solved the simplest exercises correctly and safely.

3 Learning Objects for self evaluation test: aimed at verifying what students learned declarative knowledge and operational abilities.

Learning Objects of this type are inserted into each LU. They are composed of exercises, examples and a section of self-assessment test with score. The score is simply a tool for self assessment of student learning. It provides a measure of appropriateness of learning that the student has attained up to that point. It gives the tutors the possibility to monitor the evolution of learning in the class.

Course Outline: the course contents are organized in 8 LUs.

LU 1: Introduction to the control issues;

LU 2: Mathematical Models in an Information Rich world (state space models);

LU 3: Analysis of oriented abstract systems, differential linear time invariant, finite-order, lumped parameters, real constant coefficients;

LU 4: Introduction to feedback control systems;

LU 5: Poor information models Analysis (Input-output models);

LU 6: Solution to the control problem with poor models 1 (Industrial Regulator tuning);

LU 7: Solution to the control problem with poor models 2 - Servo-systems design in the frequency domain;

LU 8: Solution to the problem of control with poor models 3 - Servo system design with root locus method.

Learning Activities: the course offers different learning activities. These are delivered in asynchronous and synchronous way and refer to different pedagogic models. Most of the online activities are asynchronous and are based on students' self-learning and self-evaluation. The LUs from 3 to 8 comprehend the suggestion and the availability of Immersive Telelaboratory activities. These can be considered in some way synchronous activities for the apparent real-time interaction with the experiments to be performed. The laboratory experiences are meant to involve the students in collaborative, experiential and reflective activities, supported and enabled by a proper didactic context and suitable tutoring.

Didactic context is constituted by:

- tutorials describing the physical process under study, the assumptions made to define the related mathematical model, the difficulties for building up such a model, the real world aspects cut away to obtain a viable model, the characters of the physical devices involved in the experiment;
- summaries of the control theory relevant for the problem under study;
- a simple VR environment where the students can observe the representation of real experiments performed on the given physical process. It is a VR environment where the avatar of the physical process is driven by data and signals collected on the physical process itself;

- a GUI, where the student can specify the experiment he/she will perform and its main parameters;
- tools for the interaction with the Laboratory administrator and with the colleagues belonging to the group involved in a given experiment;
- a simplified e-portfolio space where results deemed significant (both satisfactory and unsatisfactory) can be stored by the students together with their reflections on the experiment performed.

It is self evident that these activities involve a certain level of organization complexity in case of large classes following compulsory courses. Complexity refers in particular to time management and to the proper level of cognitive load required to students. Time management will be discussed in the context of the architecture of the Immersive Telelaboratory.

As far as the cognitive load is concerned, recent theories take into account learning design implications of the human cognitive architecture. It is well recognized that the subjective measure of the cognitive load is related to the student' cognitive resources directed towards achieving certain learning objectives [6], [7]. The IT in the context of a compulsory course for undergraduate students is aimed at the attainment of a medium-high level of competence. This one cannot be considered the learning objective of all the students, neither of a majority of them that could be interested only in obtaining the credits associated to the course. For these students the cognitive load related to IT will appear too large and therefore it could be an element hindering the attainment of a reasonable mastery of the operation solution of the problem. This level of mastery is somehow higher with respect to the learning objectives of the whole course. Therefore such an activity is offered to the interested students to be freely undertaken, while the other on-line activities are considered essential part of the learning process.

For the interested students the constitution of small groups is suggested. Three to five people constitute the group. Schedule of the activities is usually arranged on a weekly base. The roles and tasks within the Group are the following:

- *Coordinator*: early in the week he/she sends the first message to the group in the forum with details of roles, general organization and agenda of the week; he/she cares the management of eventual meetings in presence, and the management of potential conflicts. He/she acts also as moderator, animates the communication in the forum with the support of the tutor, organizes and creates new categories for better organization of the Forum.
- *Editor*: publishes within 24 hours to the deadline, the diary of the week (five lines about what really happened in the group during the week); he/she is in charge of editing the final presentation of the group work.
- *Researcher(s):* each week he/she finds and provides to the group at least two significant references (websites or papers).
- *Devil's advocate:* he/she is a critical observer. The duty is to weekly express criticisms and suggestions on the product developed.

The group autonomously decides the roles. The groups have to interact with a teacher competent in the laboratory practice and capable to enable their activity (Laboratory Administrator).

Evaluation: the summative evaluation is carried out by a F2F exam where the students have to answer three questions. One of them is specifically relative to operational abilities and has to be answered in writing. The participation on Telelaboratory activities is not a matter of the summative evaluation. If satisfactorily undertaken it provides a bonus that will be added to the exam score.

Pedagogical models: F2F lessons and information materials follow a substantially directive approach. In synthesis the teacher supervises and directs F2F activity. Lectures and exercises are accompanied by self-assessment tools designed to assist students in the understanding and acquisition of the theory and of operational skills. In this case a constructivist approach is explicitly followed [8].

The Telelaboratory activity follows a constructionist approach. It is an experience built in relation to a problem well defined in a theoretical way that puts the student in touch with aspects of the problem not explored during lectures and numerical exercises. These aspects deal with the real operation conditions of an engineering system asking for proper control to attain a performance aligned to given requirements (MK).

As already mentioned the laboratory experiences are meant to involve the students in collaborative, experiential and reflective activities, supported and enabled by a proper didactic context and suitable tutoring.

B. Team Teaching Approach and Teacher Roles

Different kinds of knowledge and different pedagogical approaches are tackled in the delivery of the course. Therefore it could be self evident that different teachers with specific competences should be involved to attain the required learning/teaching efficacy. At a first glance a three teachers model would be appropriate. According to this model the roles of the teachers would be complementary: the coordination and the most directive activities are in charge of the responsible of the whole course, the F2F activities promoting active participation of the students (numerical case studies) are in charge of another domain expert, the on-line management and support for Immersive Telelaboratory are in charge of a laboratory technology and operation expert.

The asynchronous online discussion is promoted by the use of some Forum. Two kinds of Forum are available:

- a General Forum for the interaction with the first two teachers of the course; Questions and Answers relative to theory and numerical case studies are meant to be posted in this Forum. A fixed time limit for answering is guaranteed by the relevant teachers;

- a Collaboration Forum with discussion spaces for small groups of students (3 or 4 people), is foreseen. It is moderated by the third teacher (the one dealing with MK involved in IT activities).

According to a constructionist approach the aim of this interaction is knowledge sharing among the students and with the expert. For this purpose mentoring is a critical point. Mentoring has to be the duty of the expert of the relevant MK. In fact the success in learning MK is heavily related to the availability of an expert showing it in a perceivable manner. However the contribution of the other two teachers is deemed necessary. These are domain experts, namely Control Systems analysis and design theories and techniques experts, the third one has to be expert of physical process and physical implementation of control devices and apparatuses. This latter has to provide arguments for the reflection, the other two have to assist in the development of the reflections, by giving suggestions and asking questions that help the students to integrate in their cognitive models theory, operation and MK. The aim is to reflect together in a specific tutored forum and to produce an essay collecting the student's reflections on the experiments.

It is evident that such an approach is useful and significant not only to improve students' learning, but also to enrich the teachers competencies, in particular in case of young teachers with experiences limited to specific sectors of a very broad domain like Control Systems.

III. THE ARCHITECTURE OF THE IMMERSIVE TELELABORATORY

To overcome the organization, structure and cost involved in providing laboratory facilities for a potentially large number of students, an IT has been implemented and integrated within the University Moodle Learning Environment.

The architecture of the whole LE is illustrated in figure 1.

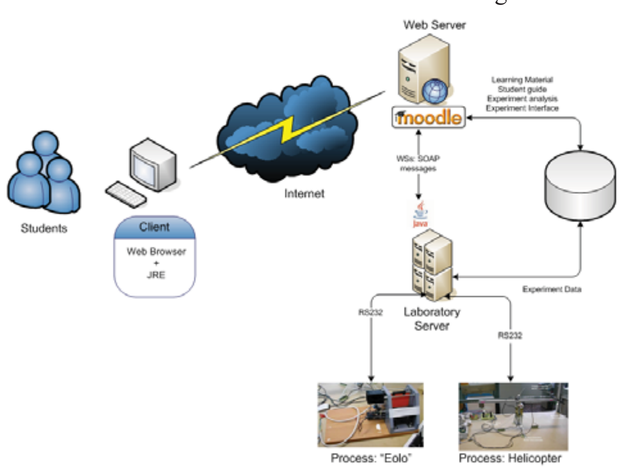

Figure 1: The architecture of the Immersive Telelaboratory

A module named MoodleLab has been developed and installed in Moodle.

With this new module, the integration of different functions in one collaborative Virtual Learning Environment (VLE) has been made possible: the learning materials, the tutorial for the conduction of the experiments, a reservation system, tools for remotely running experiments, tools for the analysis of experiment's data and some collaborative tools such as forum and chat is the whole set of tools made available. They allow the friendly implementation of the three main categories of Didactic Variables [9] relevant for an institutional course in technical scientific domains: What to learn, How to learn, and the time schedule of the learning process.

Main characters of the implemented module are:

1) The authentication of enrolled students follows standard procedures already present in Moodle. As far as the Roles considered in Moodle are concerned, the role of "Lab Manager" has to be defined for management of the experiment. To manage the experiments running it has been necessary to add to the MOODLE DB some important tables, including those relating to the accreditation of test and data collection.

2) The students access the Telelaboratory through a specific booking system. The student must choose the time period and the type of experiment among those offered during the course. The booking management is made through the LCMS MOODLE by the integration of the MOODLELAB module with the BOOKING module. This is a key issue with respect to student's time management.

3) During the booked period, the students connect to the chosen activity of Telelaboratory. The Laboratory Manager authorizes the execution of the experiment. Once enabled, the student invokes a Web Service through a specific Java applet for the experiment previously chosen. The application that manages the experiment will interface directly with the LCMS.

4) The student enters the data, starts the experiment, can display the output data through continuous or segmented charts, and can view the process by a WebCam that allow the real time vision of the physical devices.

5) After each session, the data relative to input, output and selected parameters are recorded, if confirmed by the user, in the DB "MoodleData" connected to the LCMS Moodle.

The students can perform different experiments on different physical processes: helicopter, fan-plate and robot mobile.

Figure 2: The processes of the Immersive Telelaboratory

The process called “helicopter” is a system with two degrees of freedom – pitch and rotate -, simulating the operation of a helicopter. The regulation of the process attitude has to be attained in presence of disturbances. The second process, called “Fan-Plate or EOLO” is a system with one degree of freedom. The attitude of a plate exposed to an air stream produced by rotating wings has to be controlled. There is a third process, constituted by an autonomous vehicle that has to be driven in a partially structured environment. It is not offered to the students of the Course here considered, because of the involvement of further methodological issues.

For each process, different experiments can be executed, ranging from the elicitation of the process output in response to standard inputs (open loop experiments) to the tuning of regulator parameters in various operation conditions (closed loop experiments).

The general rules, established in the official documentation of Moodle [10] have been followed for the development of the code. In the same module the database that interfaces with Moodle and with data coming from the laboratory was developed in XML [11], according to the indications given by the Moodle documentation.

It appears that in the learning environment, built up in this way, the Moodle platform plays the role of the Web Service client; the Web service at the server side is implemented by Java applets that interface with the microcontroller driving the motors propelling the devices.

The client has been implemented via a suitable Php function.

The server-side application has been implemented in Java language. It allows at one side the communication to and from the microcontroller, and at the other it manages trough a Web Service the data coming from the client for the activation of the applet.

The application has been implemented on a Linux server with Fedora distribution, with the Apache Web server, for the interpretation of PHP, Tomcat, to run the WSS, and the MySQL DBMS for managing data have been installed.

One important feature of the IT integrated in Moodle is the Portfolio of the experiments, in which each student group can save the work performed, can retrieve the input values, view charts, reproduce the behaviour of the process in a virtual environment fed by the real data.

A. Reflexes on Team Teaching

As mentioned in the previous section, course and courseware design, implementation and delivery followed a three-teacher model [13]. The responsible of the whole course has the coordination and most directive activities, numerical case studies are in charge of another domain expert, a technology expert gives on-line support for MK management. Given the relative complexity of the IT architecture and of the whole Learning environment, it is apparent the need of a fourth teacher managing the LE use and IT access administration.

It appears that a four teacher team would be ideal for the described experience. In particular the MK owner seems essential for the IT proper exploitation in order to provide the students with design competences.

The smooth operation of such a team can be a critical argument, due to the different and possibly conflicting commitments that the teachers can have in their professional activities. In fact, when teachers are expected to work together in one class criticalities related to practical or interpersonal issues, rather than to clashes in ideology or personality, can arise and serious difficulties can be encountered [14].

IV. STRENGHTS AND WEAKNESSES OF THE EXPERIENCE

The experience conducted has so far shown some strength mainly related to the improvement of teaching/learning effectiveness and to the openness to innovative teaching strategies. Notice that the experience has been performed in a not completely systematic way, so that the positive attained results about the quality of learning cannot be considered sufficient for an empirical study. A structured empirical study is planned for the coming Academic year. It will involve a structured monitoring activity relative to both the smooth delivery of the course and the student’s and teachers satisfaction appraisal.

The main points we already experienced and we would put into evidence are:

- Instructional design becomes a critical issue, especially as it applies to the development of instruction for novices. In fact, within the presented learning scenario students can be considered to be novice designers who do not yet possess the underlying mental models [15]. In this case, a teaching approach which moves from a more directive approach towards facilitating and mentoring seems to provide effective results.
- With respect to the IT, maintenance and supervision of the physical devices into the lab and level of students’

awareness of the MK involved in its proper use are also critical issues. The extension of the Team Teaching model to the four teacher's team could have important effects on the teacher's time management problem and on the effective coordination of the work. When it finds a satisfactory solution the quality of learning is significantly improved. Moreover it appears that the use of synchronous online tutor-students interaction could greatly improve student awareness of MK.

- Team teaching could be an essential experience both for teachers and for students. From the teacher's point of view, it is important a clear definition of activities and then the choice of the proper pedagogical model. A clear definition of an (inter)relations' model among actors is also needed to support teachers' coordination and leadership management. At this step, to analyse teachers' profiles and to clearly define roles is a fundamental task.

The modalities with which this interaction can be improved can be further investigated, as well as the students' reactions to the proposed team teaching model, in order to be able to facilitate learning and to improve interaction with the different teachers in future. In particular, it would be interesting to investigate in deep the students' reaction to the presence of different teachers, how the different roles are perceived and if they are perceived and, finally, how they can be better perceived by the learning group in a team teaching context. In fact, some students may feel frustration and discontent about having more than one teacher.

Nonetheless, team teaching seems to represent a great opportunity for the personal and the professional development of teachers, who are required to make a step forward and to develop new competences and new work practices, requiring cooperation and interaction with other colleagues. Collaboration is a process that happens if particular instrumental abilities subsist, not only related to the domain of expertise. Behavioural aspects of collaboration and communication are also important.

Team teaching requires the most mutual trust and respect between teachers and requires that they are able to mesh their teaching styles [16]. The creation of a community of practice [17] [18] to support teachers within the educational institution may help. It could happen in either informal or formal manner, but the support of the management is crucial.

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Enhancing Learning Systems by using Virtual Interactive Classrooms and Web-based Collaborative Work

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Abstract— **There are many e-learning web sites and e-learning systems that are available with excellent content and design but they generally lack interactive response and face-to-face communication. Students cannot ask questions and get responses immediately. It is similar to one way communication for learning. However, learning is most effective when it actively constructs knowledge during group social interaction and collaboration. Therefore, this paper proposes to inspire creativity in e-learning called the virtual interactive classroom by using RTMP (Real-Time Messaging Protocol) which is a sophisticated TCP-based real-time networking protocol which supports the efficient exchange of messages, synchronized data, audio, and video. Teachers and students can publish streaming audio, video and other data messages to present streaming media with interaction or navigation. Using this virtual classroom on the internet, students can immediately interact with teachers as though they were studying in a real classroom. In addition to the virtual interactive classroom, this article also proposes using web-based collaborative work as an add-on feature to the learning system. Both teacher and student can use web-based collaborative work for sharing resources and exchanging ideas after the class. The integration of the two concepts of the virtual interactive classroom and web-based collaborative work in order to enhance teaching and learning performance has been created.**

Keywords- learning system; virtual interactive classroom; web-based collaborative work, Wikis

I. INTRODUCTION

Advances in technologies such as streaming video, virtual learning environments and teleported experiments are entering the Web-based learning arena [19]. Along with the development of a second-generation online education infrastructure, it will be necessary to consider changing the interface of web-based education such as reinventing pedagogy for the new interface, including multimedia and hypermedia enhancements as well as creating the educational standards necessary for generalized deployment. Instructional learning goals should drive media selection, applications, and the course development process. Characteristics of the distance learner and the impact of technology are also important considerations in instructional media selection and course development. The new streaming technologies have made it easier than ever for people to receive a quality education by bringing the classroom to the student. Imagine, a teacher at one university campus delivering a lecture while students in a classroom two cities away watch the same lecture in real time. In a residence hall not far away, a student recovering from an operation watches a lecture recorded from an earlier class he or she had missed that is delivered on-demand in the comfort of his or her own room. In a city 5,000 kilometers away, a student is using the on-demand lectures to take part in the same course delivered completely online [6]. With the advent of streaming technology and the possibilities it creates, scenarios like these have been repeated all over the world.

In addition to the virtual interactive classroom, this article also proposes web-based collaborative work as an add-on feature to the learning system. Teachers can assign a task or a group task as homework to the students after studying using a real-time internet classroom. They can also manage group work using the various tools provided in an application. They can use the system to monitor and evaluate the student's behavior during collaborative work. Students can collaborate or help each other and generate additional ideas to solve a given task. Using the two important features – the virtual interactive classroom and web-based collaborative work- in a learning system, both teachers and students can greatly benefit from distance learning. These features will enhance the performance of teaching and learning for distance learning. The key goals for this research were the development of: (a) a lightweight virtual interactive classroom, and (b) a web-based collaborative application.

This article is organized as follows: Section II addresses about the related work. Section III addresses a design framework for web application. Section IV describes about supporting technologies in more detail. Section V describes the implementation. Section VI presents conclusion and gives some perspectives and ideas for future work.

II. RELATED WORK

Traditional study using a blackboard provides a rich interaction between lecturer and learner that cannot easily be replaced with a PowerPoint slideshows. Satoshi Ichimura et al present a ChalkTalk system [20]. It is a system that automatically produces e-learning materials from a videotaped chalk talk lecture in front of an ordinary blackboard or whiteboard. But this approach lacks interaction activity. The Learning Activity Management System (LAMS) [12] provides more student interaction such as question and answer (with student answers shared with the group), asynchronous discussion forum, and synchronous chat. Based on the pilot evaluation of LAMS, only 15% of students were willing to discuss ideas in front of their peers in the classroom, but over 80% of the same students were willing to discuss their ideas within LAMS. E-learning provides for self-managed learning such that the learner can study when they want, but some people still like traditional teaching, where the lecture times are fixed [18]. Tungkasthan, et al presents an implementation of an interactive virtual classroom on Internet [23]. They implement several methods for the efficient exchange of messages, synchronized data, audio, and video by using a real-time messaging protocol. Their application allows multiple connected users to share data and user interfaces in real time. Currently, there are many collaboration and communication programs on the market such as NetMeeting, CollabWorx Virtual Classroom, Breeze, MSN, or Skype. Some programs are free and some are not. Each program has pros and cons. Let's us consider the features offered in each program.

NetMeeting [16] is a synchronous online collaboration and communication program. This means that NetMeeting collaboration with others happens in "real time." NetMeeting allows users to implement online meetings, hold online classes, and conference with individuals no matter how distant they may be. Some of the NetMeeting features also allow for efficient communication with people with certain disabilities such as hearing or mobility impairments. NetMeeting is an application sharing, which is suitable for online meeting or video/audio conference. The program still lacks some essential features for online virtual classroom such as classroom control, presentation control, and content review.

CollabWorx Virtual Classroom [5] is a complete software solution enabling interactive, real-time delivery of corporate training or academic classes over the network. The process involves an instructor and support personnel at one geographical location and a group of students at remote locations. Both parties (instructor(s) and students) use desktop computers as the only communication device. The notion of "remote" encompasses distances from "across the hallway" to "across the continent." This program contains full functionalities for online classroom but it still lacks of some interactive response portions for the students.

Skype [21] is a peer-to-peer Internet telephony network. Skype has experienced rapid growth in both popular usage and software development since launch, both of its free and its paid services. The Skype communications system is notable for its broad range of features, including free voice and video conferencing, its ability to use peer to peer (decentralized) technology to overcome common firewall and NAT (Network address translation) problems, and its extreme countermeasures against reverse engineering of the software or protocol. This program is not appropriate to apply with virtual classroom because of lacking tools for class management and learner collaboration functions.

Macromedia Breeze [2] is software used with Microsoft PowerPoint to create information and general presentations, online training materials, web conferencing, and learning modules. Macromedia Breeze includes four applications: Breeze Presenter, Breeze Training, Breeze Meeting, Breeze Events. This program is generally designed for conducting a meeting purpose not a virtual classroom but it can creatively apply to virtual classroom as well.

Sakai [24] is an enterprise application that supports teaching, learning and scholarly collaboration in either fully or partially online environments. It provided powerful functions with a suite of capabilities for faculty, students and staffs. Some of the many available tools in Sakai include general collaboration tools, teaching and learning tools, portfolio tools, and administrative tools. Moodle [25] is similar to Sakai. Moodle is an open source course management system (CMS). It is very popular among educators around the world as a tool for creating online dynamic web sites for the learners. Moodle has several features such as module, quiz module, forum module, and resource module that allow it to scale to very large deployments and hundreds of thousands of learners. However, such main features available with Moodle are essentially provided and supported for individual interactive learning. Although, there are the rich array of tools and features that are available with the Sakai and Moodle but such tools are mainly used for non-interactive mode.

Another technology enhanced learning approach proven to enhance especially informal learning is the application of Wikis as collaborative online tools [10]. Wikis are a technology developed by Leuf and Cunningham in 1995 [15]. They are designed to provide a simple tool for knowledge management, with users being able to collaboratively create and edit pages. Another of the central aspects of a Wiki is the revision history tracing every modification to a specific user. Recently, tools like wikis are being used to support collaborative aspects in e-learning [8]. With the power of Web2.0 technologies, wikis seem to be an appropriate tool for exchange between high numbers of learners. Lot of different research work carried out that wikis can successfully be applied in education [3], [7]. Wikis in general highly support the characteristics communication, collaboration and contribution to a pool of knowledge. Depending on the degree of freedom as well as the possibilities of active contributions within a learning community successful learning occurs [4], [17]. Furthermore, there is an impact for graduates on cooperative developing new knowledge as solving problems [13].

III. A Design Framework for Web Application

A. A Framework and its Functions

There are two main components in the proposed design framework for the web application. First, it is a virtual interactive classroom. There are some requirements that should be taken into consideration such as: 1) shared object component, and 2) VDO streaming component. In the first component, there are many objects such as a white board, presentation, chat, AV presence and list of people in the interactive classroom on the internet. These can be shared with other students. Remote shared objects are managed by a streaming server. Clients can access shared objects and get updates whenever a change is made to a shared object. The VDO streaming component is also provided by the streaming server. Second, it is a web-based collaborative work component. It consists of a workspace, chat room, comment tool, and e-mail. The framework and its details are shown in Fig 1.

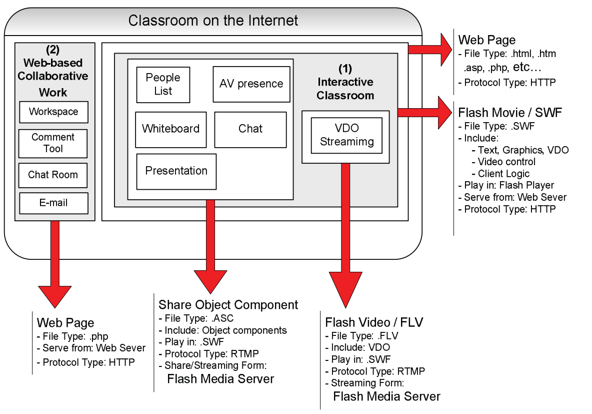

Figure 1. Top level design and classification function of virtual internet classroom.

B. *Client/Server Sequential Process for Virtual Interactive Classroom*

There are four steps in the sequential process utilized to obtain streaming objects. First, a client requests the HTML and SWF files by using HTTP on a TCP connection. Second, the web server sends HTML with embedded links and SWF files back to the client according to their request. Third, the client sends a message to a flash media server by using the RTMP protocol. Fourth, shared FLV files and streaming media are sent back to the client. The general connecting and displaying of shared files as well as streaming media are shown in Fig. 2.

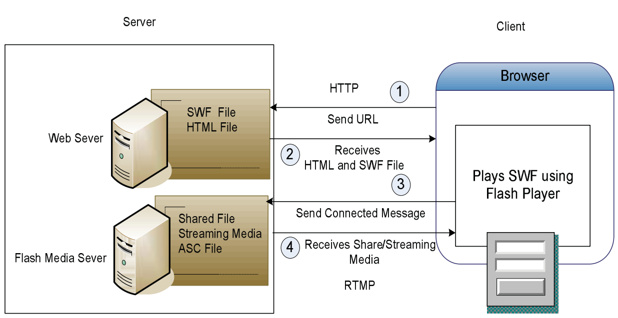

Figure 2. Procedural sequence steps in general connecting and displaying share and streaming media.

C. *Collaborative Functions for Lecturer and Learner in a Virtual Interactive Classroom*

1) Login function: When a student or teacher wants to enter the classroom, they must login with the correct username and password. In the classroom, they are allowed to use shared objects or resources.

2) Whiteboard function: The purpose of using this function is to provide a collaborative environment for students and teachers. They can write messages in text format and draw lines on a shared whiteboard environment in real time. When they want a message or line, they must select tools by dragging and dropping them on the whiteboard. They can also delete objects by pressing the delete key on the keyboard. Students can write or erase any items at any time they want. Students and teachers have equal authority in this classroom.

3) Presentation function: This function allows creating a presentation in SWF format. This function contains two modes. The first mode is the teacher mode. The teacher can fully control the presentation. Students can see the same presentation frame simultaneously. The second mode is the student mode. Students can navigate the presentation by using next and back buttons in order to view the presentation. They are not allowed to control the presentation that the teacher is using. The presentation function requires an SWF presentation file.

4) Chat function: This function supports teacher and students for chatting in regular text format. They can send message to their friends in the same classroom. Text can be selected in different styles.

5) List of learners: This function displays teacher and student names that are logged into the classroom. All usernames appear on the list in the classroom and are used to identify who they are.

6) Audio/Video presentation function: This is very important function for providing face to face communication. A VDO camera and microphone are essential for this function. The teacher and his/her students can send and receive audio and video within the same classroom. If someone is sending audio or video or both, the other people in the classroom can see and hear it.

D. *Web-Based Collaborative Work*

The web-based collaborative application was developed using a wiki-style, WikkaWiki [11]. It provides several features such as a workspace, comment tool, chat room, and e-mail. Teachers and students can communicate with each other by editing text messages in the workspace. Teachers can assign tasks in the teacher's workspace and students can put the solutions to such tasks in their own workspace. Teachers can post a comment to the students or students can communicate with teacher or their colleagues using the comment tool. A chat room is also provided for them to communicate with each other in real-time. An e-mail system is provided to them for sending and receiving e-mails more smoothly and conveniently.

IV. Supporting Technologies

A. *Overview for Flash Media Server Architecture*

The Macromedia Flash Media Server (FMS) platform consists of two parts: the server, which provides the means of communication, and the Macromedia Flash Player. Applications consist of a client Macromedia Flash Movie (SWF file) that is run by the Flash Player. Server components are shared with all clients. The server component minimally consists of an application folder that we have created on the server side running the Flash Media Server. This folder can optionally contain Server-Side Communication ActionScript (ASC) files and other resource files used by the communication application. The server and the Flash client application communicate over a persistent connection using the Real-Time Message Protocol (RTMP). In a typical scenario, the Flash client is delivered to the Flash Player by a web server over HTTP. The Flash client then establishes a persistent connection to the Flash Media Server using RTMP, allowing for an uninterrupted data stream to flow between the client and the server [9], [22]. The RTMP protocol of communication for Streaming media is shown in Fig. 3.

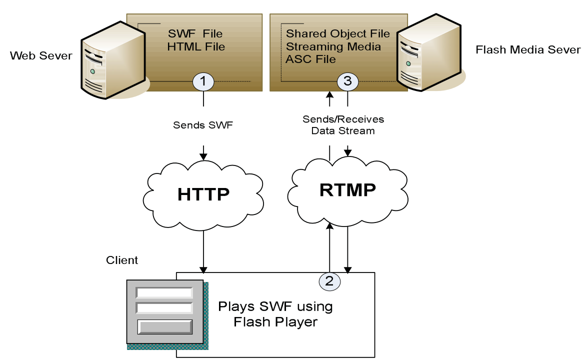

Figure 3. Flash media server provides a RTMP protocol of communication for Streaming media for client.

B. *RTMP*

The Real-Time Messaging Protocol (RTMP) is a protocol for client-server communication. It is a proprietary protocol developed by Adobe Systems (formerly developed by Macromedia) that is primarily used with the Macromedia Flash Media Server to stream audio and video over the internet to the Flash Player client, but can also be used for general remote procedure calls (RPC). RTMP is basically a TCP/IP protocol designed for high-performance transmission of audio, video, and data messages [14].

C. *Client-Server Connection Flow*

When the client connects to the server, the server calls the application start method to run. Next, the server-side will make and hold the connection. The logic in this method determines whether to accept or reject the connection. Back on the client side, the "on status" handler is called to report whether the connection was accepted or rejected. When the client closes the connection, the server-side disconnects and closes the session [1]. The connection flow between clients the server is shown in Fig. 4.

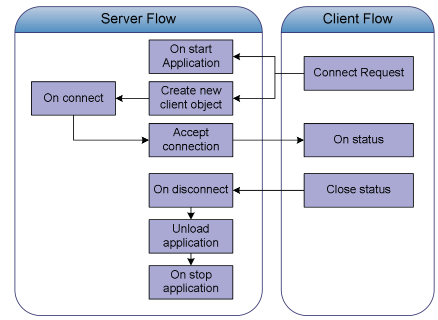

Figure 4. Connection flow between clients and server using RTMP protocol.

D. *Shared Objects*

Remote shared objects are managed by the Flash Media Server. The server provides messaging, data synchronization, and data storage services. Flash clients connect or subscribe to a remote shared object and receive updates whenever a change is made to that shared object. Also, messages can be sent to all clients connected to a remote shared object. A remote shared object can persist across application sessions, or be temporary [1]. The shared objects provide data storage and synchronization services for clients are shown in fig. 5.

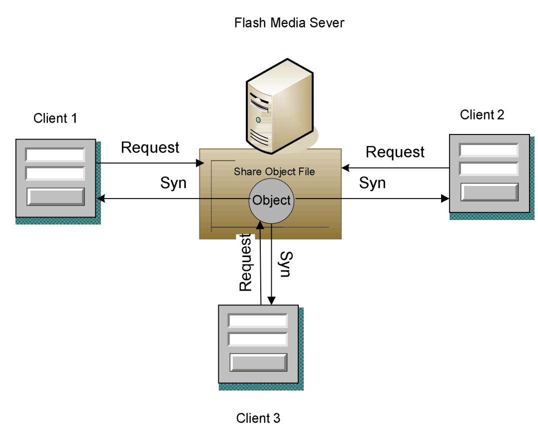

Figure 5. Shared objects provide data storage and synchronization services for clients.

E. *A Lightweight Wiki Engine*

The web-based collaborative application was developed using a wiki-style, WikkaWiki[11]. WikkaWiki is a lightweight wiki engine written in PHP, which uses MySQL to store pages. It can be easily extended or adapted for many different uses. By setting the appropriate access privileges and using appropriate actions, the user can turn WikkaWiki into different applications, tailored to user needs. The traditional idea behind the concept of a wiki is to create a digital blackboard on which any user, either registered or anonymous, can write modifications and add comments. WikkaWiki can be used as a public wiki, discussion forum, blog, invisible backend for a personal website, intranet CMS, personal organizer and memory support, presentation framework, community-maintained user manual, and etc.

V. IMPLEMENTATION

A. Participants

Thirty undergraduate students who registered in the multimedia course in the computer engineering department at Siam University were recruited to participate in the virtual classroom on the Internet application for a semester which lasts for four months. The teacher and students use a virtual interactive classroom on the Internet instead of using a traditional classroom for learning and teaching.

B. Virtual Interactive Classroom and Web-based Collaborative Work

1) A Virtual Interactive Classroom: We installed the virtual classroom as an Internet application on a streaming web server. A Flash media server and IIS must also be installed on the server. We tested the application and corrected the bugs in the application for two months before it was ready. The client side must contain the flash player application in order to display flash movies correctly. The experiment is set up and run on a windows platform. Fig. 6 shows a screenshot of a user login web page. A student and teacher must login with the correct username and password to enter virtual classroom. In the classroom, they are allowed to use shared objects or resources. Fig. 7 shows a screenshot of a virtual interactive classroom. The classroom has four main portions: 1) the picture screens for the teacher and students, 2) a workspace, 3) a list of people screen, and 4) a real-time chat screen. In this virtual classroom, the teacher has the full authority to control all kinds of things such as a white board, presentation, chat, and audio/video presence by clicking on a menu item above the workspace. For example, the teacher can just click on the presentation button to control the powerpoint slideshows. The students cannot edit any contents of the slideshows. Next, the teacher clicks on the whiteboard button to change the workspace to a shared whiteboard. This feature allows anyone in the classroom to edit text messages or draw a picture on the whiteboard. The VDO feature is used in two aspects. First, the teacher clicks on the VDO button to select the VDO file in the computer and play it. Second, the students click on the VDO button to record what their teacher is teaching. Moreover, the teacher can talk to the students and/or the students can also talk to their friends in the classroom through a microphone. The teacher can mute the voice of any students by clicking on the mute button. Using a web camera, they have access to a large amount of information about one another. The students can observe how their friends feel physically and emotionally. Both teacher and students can enter a web-based collaborative work by clicking on the Collabwork button. Fig. 8 shows a screenshot of a whiteboard function.

Figure 6. A screenshot of a user login web page.

Figure 7. A screenshot of a virtual interactive classroom application.

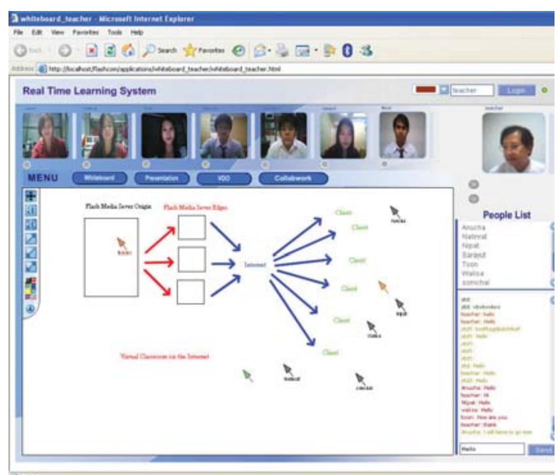

Figure 8. A screenshot of a whiteboard function.

2) A Web-based Collaborative Work: A web-based collaborative work capability was installed on a web server. It was created for a teacher who taught a multimedia course and used it for managing tasks or assignments for the students. The teacher posted a task every week on a teacher's workspace.

The students were arranged into teams to solve the given task. Using a web-based collaborative application, the students can collaborate or help each other to solve the given task, share the resources and materials, and generate additional ideas through the student's workspace and in the comment area. In addition to the task assignment and problem solving, the teacher can use this tool to monitor the progress of the given task and the student's behavior during an online collaborative work. The screenshots of the web-based collaborative work application are shown in fig. 9, 10, and 11.

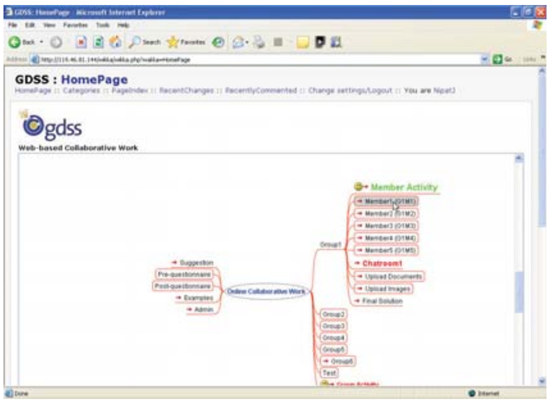

Figure 9. A screenshot of a web-based collaborative work homepage.

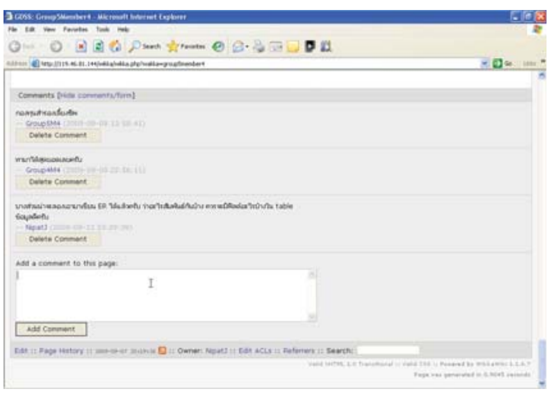

Figure 10 A screenshot of a comment tool in a web-based collaborative application.

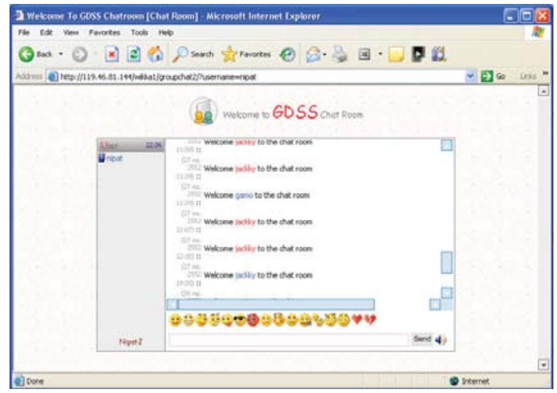

Figure 11 A screenshot of achat room in a web-based collaborative application.

VI. Conclusion and Future Work

This article presents the potential of integrating two concepts, namely those of a virtual interactive classroom and a web-based collaborative work application in order to enhance teaching and learning performance in distance learning. In addition to the concepts, the framework has been designed and implemented. The virtual interactive classrooms and the web-based collaborative work application work well according to their predefined functions. They can work as a substitute for any classroom in the school. With the use of computers and information technologies, the barriers of space and time can be eliminated. This virtual interactive classroom is an opportunity for a number of students in rural areas with homes that are far away from a school. They have a chance to study and communicate with the teacher and other students. We do not mean to imply that by using this virtual interactive classroom on the internet that it is better than the real classroom in the school but it is a choice in order to move schools closer to students who lack of the opportunity of physically attending a school. We want the virtual interactive classrooms on the internet to be one standard feature of several possible features for e-learning or distance learning.

In future research, based on this study, we intend to summarize the feedback received from teachers and students and take the results and recommendations obtained from the experiment into the consideration for improving the quality of the virtual interactive classroom and web-based collaborative work application in the future.

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How Can Apache Help to Teach And Learn Automatic Control?

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Abstract— **Searching for examples to encourage and motivate students in a subject is not a trivial task. Future Computer Science and Telecommunications Engineers tend to look at Automatic Control reluctantly. They do not relate their working life to it. But, if we blend examples from two areas: telecommunications and control, maybe we can change their minds. These engineers work with web servers: systems that deal with a lot of requests and must give fast and reliable service to users. CPU and memory usage could improve their performance if automatic control techniques are applied. Apache is one of the most well known web servers and it is at this point where Apache can help us.**

Web server; Apache; Automatic Control; Internet server; PID; predictive control.

I. Introduction

Automatic control combines concepts and ideas from Mathematics and Engineering. There are many different techniques that allow real systems to be controlled. For instance, we can apply control techniques to ensure that a reactor does not reach a critical point, or we can control an airplane velocity or altitude.

Future Computer Science and Telecommunications Engineers (in Spain) learn about Communications Networks and Internet and they also learn automatic control techniques. It is sometimes difficult to find systems that appeal to them from both sides: communications and control. Most control books present electrical or mechanical examples. Rerefence [1] is the only textbook that gives examples of computing systems and how control techniques can improve their performance.

Apache ([2]) is a web server developed and maintained by the contributors to the Apache Software Foundation. There are variables that are critical for the right performance. As presented in [3], we can apply automatic control techniques to achieve better server performance. It should be decided which variables will act as inputs or manipulated variables and which variables will be the outputs or controlled variables. The work in [3] is used as reference. We aimed to design a tool that could be used in the classroom and act as a pool of control techniques to experiment and compare results.

CONAPA (CONtrolling APAche) is the user's tool. It has been developed taking into account that it should be easy to use. There are different working options:

- Monitoring tool: the user watches the system's evolution.
- Simulation tool: the user can simulate the system under different situations.
- Real-time control: the user defines the controller parameters and the real web server works following the controller calculations.

It works both as an online and as a virtual laboratory. Data can be saved and loaded in different programs to analyze results. This application manages the data capture for identification purposes, the simulation environment and the control of the real system.

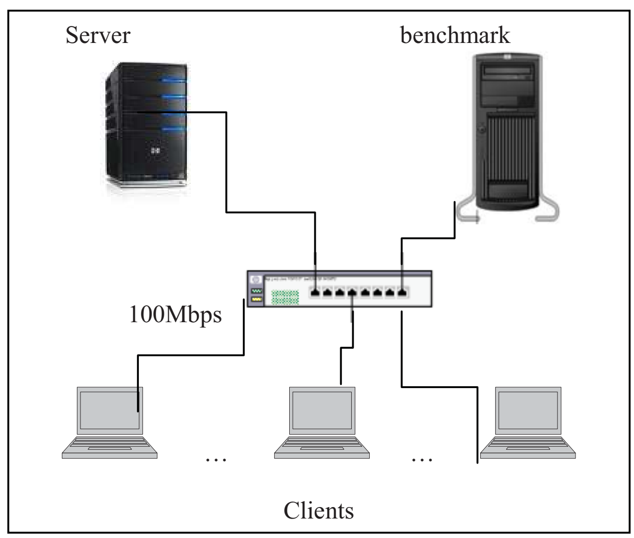

Figure 1. Working environment

The following sections describe our work. We have followed a top down approach, from general to particular. So Section II describes the system's architecture. Then the relevant variables are explained as well as how they are read and calculated from the server in Section III. Section IV

This work was supported in part by the Junta de Castilla y León under Grant VA037A08 and by the CICYT under grant DPI2007-66718-C04-02

describes the new module included in Apache. Then, a brief description of the type of controllers that are implemented is given in Section V. CONAPA is presented from the user's point of view (Section VI) and finally some conclusions and future work are outlined.

II. System's Architecture

The working environment () consists of a server running the modified Apache connected through a 100 Mbps LAN to a machine running a synthetic workload generator. Thus, we can work under different traffic conditions. The server is a Pentium IV Mobile 1.8 MHz (2GB RAM memory). The benchmark runs on an Intel dual core 2.24 MHz (4GB RAM memory). Both machines run under Ubuntu (www.ubuntu.com).

The clients' machines will connect to CONAPA's web page. From there, they could work with the different options that will be explained in Section VI.

The benchmark is Curl-Loader ([4]). This tool is open-source and written in C. It simulates the application load and behavior of HTTP/HTTPS and FTP/FTPS clients. Information about each virtual client can be statistically analyzed.

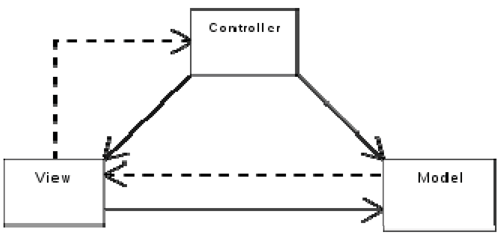

Figure 2. MVC architecture

Our application has been developed using the LAMP (Linux, Apache, Mysql and Php) architecture ([5]). The software architecture, i.e., how the system is organized inside, follows the Model-View-Controller (MVC, Figure 2) architecture (first described in [6]).

III. System's variables

Choosing manipulated and controlled variables is directly related with how and what we want to do. It is advisable to choose variables that have a real importance in the system and that can be easily modified and interpreted. There are several key variables in an Apache web server.

From the administrator's point of view, it is very important to keep the CPU and memory use within a desired band (from now on, these variables will be denoted CPU and MEM). If high values are reached, the system could overload or there might be a slow response to bursts in workload. CPU and MEM cannot be read directly and should be calculated (see the following subsection). These two variables are our system's outputs.

The controlled variables change their value as the result of a change in the manipulated variables. If we want CPU and MEM to follow a reference, i.e., to reach and stay around a value, we need to find which variables could affect them, and more importantly, we need these input variables to change their value dynamically.

Apache's KeepAliveTimeout (KA, [2]) directive is the number of seconds the server will wait for a subsequent request before closing a connection. The higher the value, the more server processes will be kept occupied waiting for idle clients. So, CPU and MEM are underused. If KA is very low, connections could be terminated too early. So KA should be given values that neither overload nor underload the server.

The maximum number of clients (MaxClients, MC for short) that can connect to the Apache server directly influences the use of the CPU and MEM. The more clients are connected, the higher the usage.

MC and KA cannot be modified in standard Apache. If we want to change their value dynamically, the Apache source code has to be modified (Section IV).

A. *How to calculate MEM and CPU utilization on line*

There are tools in Linux that calculate the use of MEM and CPU, but they group consumptions together by processes and not by application. So a script was written in Python ([10]).

The script in Figure 3 looks for information from each process that has been created. Linux stores these records in the directory /proc.

```
Cpu.py
#! /usr/bin/python
import sys
import time
import os
import pwd
import math
class PStat:
   def __init__(self, pid):
        fd = open("/proc/%d/stat" % pid)
        l = fd.readline().split()
        fd.close()
        self.pid = pid
        self.comm = l[1][1:-1]
        self.utime = int(l[13])
        self.stime = int(l[14])
    def get_time(self):
        return self.utime + self.stime
class SStat:
   def __init__(self):
        fd = open("/proc/stat")
        l = fd.readline().split()
        fd.close()
        self.uptime = int(l[4])
def get_pids():
    r = []
    for d in os.listdir("/proc"):
       try:
           r.append(int(d))
       except ValueError:
           pass
    return r
def get_pstats():
    r={}
    for pid in get_pids():
        r[pid] = PStat(pid)
    return r
def get_rss_mem(pid):
    """Return the process RSS in MB"""
    fd = open("/proc/%d/statm" % pid)
```

```
    l = fd.readline().split()[1]
    fd.close()
    return int(l) * os.sysconf('SC_PAGE_SIZE') / 
1024.0 / 1024.0
total = 0
memoria = 0
tab = get_pstats()
sstat = SStat()
time.sleep(1)
tab1 = get_pstats()
sstat1 = SStat()
for pid in tab1:
    if tab1[pid].comm=="httpd":
        #load = 100.0 * tab1[pid].get_time() / 
sstat1.uptime
        load = 100.0 * (tab1[pid].get_time() - 
tab[pid].get_time()) / \
            (sstat1.uptime - sstat.uptime)
        memoria = memoria +get_rss_mem(pid)
        total = total + load
total=('%5.3f' % total)
memoria= ('%5.3f' % memoria)
   print str(total) + '\t' + str(memoria)
```

Figure 3. Memory and CPU utilization

IV. APACHE WEB SERVER

This section explains Apache's architecture at a basic level. Session flow and conceptual architecture are described first. Then, the necessary changes in Apache and how to program them are explained.

A. Apache's architecture: session flow

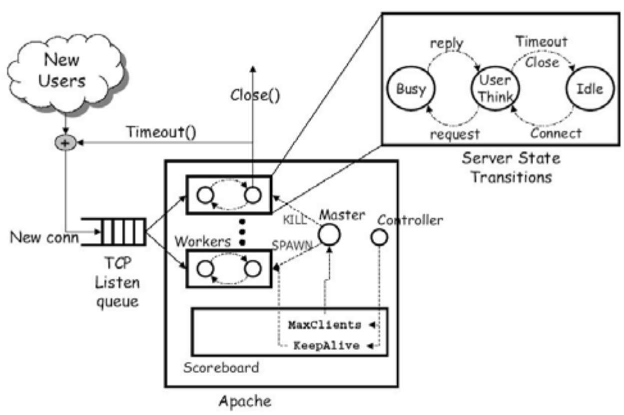

Figure 4. Apache's session flow

Although there are later versions, we are working with Apache 1.3 on Linux. This version is structured as a pool of 'worker' processes, monitorized and controlled by a master process (Figure 4). Worker processes manage the communication with the Web clients. At any time, a worker process can only deal with one connection and it is its responsibility until the connection ends. Thus, the worker process is inactive between successive petitions during the connection with the client.

MaxClients (MC, Section III) limits the size of the pool of the worker processes. KeepALive Timeout (KA, Section III) fixes the maximum time a worker process can be in the 'user think' state before the client's TCP connection is finished. If KA is too big, CPU and memory are underused. Decreasing its value, worker processes spend less time in the 'user think' state and the CPU usage increases. But, if the value is very small, TCP connections will finish before time and the benefits of persistent connections are lost.

B. Apache's conceptual architecture

Apache has a modular architecture ([6], [7], [8]) that makes it possible to increase its functionalities and customize it to our own purposes. Apache's core component defines the basic operations of a web server. The modules implement how to serve clients' requests, but the core calls the handlers in modules in a certain order that can be changed using the adequate directives.

The conceptual architecture is summarized in Figure 5. The PHP module is available to download, but it is not included in the standard installation. The mod_control.c is a new module we have written. Its main purpose is to create a socket that reads/writes KA and MC. Thus their values are updated each sampling time. More details in subsections C and D.

C. Changes in Apache source code

Configuration parameters are saved in the http.conf file. When Apache is launched, these values are read and cannot be modified until a restart of the server happens. So, MC and KA have default values that will be active all the time and cannot be changed during running time, i.e., dynamically every sampling period (the controller will calculate new values at certain time instants, sampling time and send to the Apache web server).

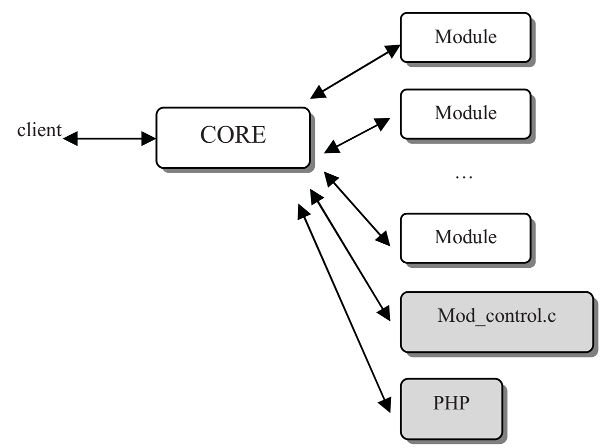

Figure 5. Apache's conceptual architecture

The first idea was to change the http.conf every sampling time and then carry out a 'graceful restart'. Thus, the parent process tells the child processes to terminate once they finish what they are doing. The new configuration file is read and the new child processes follow the new configuration. However, this approach is not very convenient because Apache is restarted every sampling time (about every 2 seconds) and only two parameters need new values. So, it was a computationally demanding approach.

The approach followed was to modify Apache's source code. Thus, MC and KA are no longer parameters, but variables. Two new modules were written. This new source code manages the variables and the interaction with the user's interface. The following sub-sections describe these topics.

D. MC and KA as variables

MC is called ap_daemons_limit and KA is called keep_alive_timeout in Apache's source code. Their declaration was changed from integer to integer pointers. Thus, the process receiving the petitions could change their value.

Changes regarding MC:

a. include/http_conf_global.h. The variable is declared as a pointer: extern API_VAR_EXPORT int * ap_daemons_limit;

b. main/http_conf.c. Shared memory is reserved:

```
Clave = ftok("/bin/ls",33);
         if (Clave==-1)
               exit(0);
         Id_Memoria          =          shmget
(Clave,sizeof(int),0777| IPC_CREAT);
         if (Id_Memoria == -1)
                 exit(0);
          ap_daemons_limit        =        (int
*)shmat(Id_Memoria,(char *)0,0);
         if (ap_daemons_limit == NULL)
                 exit(0);
```

c. main/http_main.c. The variable is declared as a pointer:

d. Other files: the variable should be addressed as the pointer's content.

Changes regarding KA:

a. Include/http.h. Pointer declaration: int *keep_alive_timeout.

b. Main/http_config.c. Shared memory is reserved:

```
Clave = ftok("/bin/ln",33);
        if (Clave==-1)
            exit(0);
      Id_Memoria = shmget (Clave,sizeof(int),0777 |
IPC_CREAT);
        if (Id_Memoria == -1)
            exit(0);
      s->keep_alive_timeout = (int *)shmat(Id_Memoria,(char
          *)0,0);
      if (s->keep_alive_timeout == NULL)
          exit(0);
```

When the new MC was smaller than the old one, Apache did not kill the excess of child processes once they had finished their job. So we wrote a method in Apache that runs periodically. It checks whether the MC (ap_daemons_limit) is smaller than its previous value (ap_maxclients_ant). If it is, the remaining processes are destroyed. This source code is in the method static void perform_idle_maintenance(void) in http_main.c (Figure 6).

```
if(*ap_daemons_limit<ap_maxclients_ant)
     {
for(j=*ap_daemons_limit;j<ap_maxclients_ant;j++)
                {
                     int status;
             if(j>=max_daemons_limit)
                break;
             ss = &ap_scoreboard_image-
>servers[j];
             status = ss->status;
             if (ss->timeout_len)
               {
               parent_score *ps =
&ap_scoreboard_image->parent[j];
               kill(ps->pid,SIGKILL);

ap_update_child_status(j,SERVER_DEAD,(request_rec
*)NULL);
             }
          }
      ap_maxclients_ant = *ap_daemons_limit;
  }
else if(*ap_daemons_limit>ap_maxclients_ant)
  {ap_maxclients_ant = *ap_daemons_limit;}
```

Figure 6. static void perform_idle_maintenance(void)

E. Apache new module

The changes explained in the previous sub-section allow the two input variables to be modified dynamically, but we need a way to send the information in and out of Apache.

A new Apache module (mod_control.c, see pseudocode in and source code in http://www.isa.cie.uva.es/~tere/) has been written. Basically, this code opens a socket on the server side and 'tells' Apache which internal parameters can be modified dynamically.

```
MODULE mod_control
 include <libreries>
 define CONSTANTS
 var variables
 PROC open_server
   IF process_can_be_created THEN
     EXECUTE  open_connection
   END IF
 END//open_server
 PROC abrir_conexion
 IF socket_cannot_be_created THEN
    ERROR
    EXIT
 END IF
 IF not_poss_to_send_inf_kernel_about_socket
THEN
    ERROR
    EXIT
 END IF
 IF not_poss_link_socket_connection_inf THEN
    ERROR
    EXIT
 END IF
 IF socket_doen't_listen THEN
    ERROR
    EXIT
 END IF
 IF no_se_puede_tomar_la_señal_socket
    ERROR
    EXIT
 END IF
 WHILE module_in_execution
   IF connection_cannot_be_accepted
      CONTINUE
      EXIT
   END IF
 IF child_process_can_be_created THEN
    IF data_received THEN
```

```
        *ap_daemons_limit=datos;
        ap_set_keep_alive_timeout(datos)
        IF confirmation_not_send TEHN
          ERROR
          EXIT
        END IF
    END IF
  END IF
 END WHILE
 END//open_connection
/* procedure that Apache looks for to execute
the module */

 PROC main
          EXECUTE  open_server
 END//main
END //mod_control
```

Figure 7. Simplified mod_control.c pseudocode

F. *php module*

The php module is installed as an Apache module, so when Apache starts, php also starts. As it is installed as shared, all the advantages of the dynamic linking/loading of *Dynamic Shared Objects* (DSO) will be available. This mechanism provides a way to build a piece of program code in a special format for loading it at run-time into the address space of an executable program ([11]).

The php application will be saved in Apache's *htdocs* directory. It is composed of:

a. User's interface. Html code that will be accessed via the client's web browser.

b. Simulation code. Scripts in php

c. Control of the web server. A collection of php scripts. The client's socket is programmed here (Figure 8 and pseudocode). This part sends requests to mod_control.c when KA and MC are needed to calculate the next control signals.

d. Access to the mysql database: queries, save data, retrieve information, …

```
<HTML>
<BODY>
<FORM METHOD="post" ACTION="socket.php">
<p>MaxClientes <input type="text" name="mc"
size="30" value=""></p>
<p>KeepAlive <input type="text" name="ka"
size="30" value=""></p>
<p><input type="submit" value="Enviar datos"
name="enviar">
</FORM>
</BODY>
<HTML>
socket.php
<?php
        // Create the socket
        if(($sockd = @socket_create(AF_INET,
SOCK_STREAM,SOL_TCP))<1)
                die("Unable to create
socket:" .
socket_strerror(socket_last_error()));
if(@socket_connect($sockd,"127.0.0.1", 3490)
== FALSE)
                die("Unable to connect:" .
socket_strerror(socket_last_error()));
        $buffer =
$_POST['mc'].";".$_POST['ka'];
        if(@socket_write($sockd, $buffer) <
strlen($buffer))
                die("Unable to connect:" .
socket_strerror(socket_last_error()));
        unset($buffer);
        if(($buffer = socket_read($sockd,
100)) == FALSE)
                die("Unable to read from
socket:" .
socket_strerror(socket_last_error()));
        socket_close($sockd);
        echo $buffer;
?>
```

Figure 8. php socket

V. CONTROLLERS

This section briefly describes the controllers that students can use to test their knowledge. We have included PIDs and a predictive controller (GPC).

The system we propose here is a MIMO. There are two inputs and two outputs, although the coupling between variables is not very strong. The reasons for choosing these two methods are: PID is the most widespread controller and students of every Engineering degree learn it. Predictive control is an advanced control methodology with a relatively important influence in industry and the MIMO formulation is inherent to the controllers. So, students can compare what happens when working with a MIMO system, but considered as two SISO ones or working with the MIMO system itself.

```
SOCKET.PHP
Create socket
If error then print('error')
Connect
If error then print('error')
Collect variables
Write variables in socket
If error then print('error')
Read variables
If error then print('error'
Close socket
```

Figure 9. php pseudocode

A. *PID*

The PID [13] is the most common form of feedback. Its continuous formulation can be described by (8):

$$u(t)=K_p\left(e(t)+\frac{1}{T_i}\int_0^t e(\tau)d\tau+T_d\frac{de(t)}{dt}\right) \qquad (1)$$

The PID implemented in the computer follows the guidelines in [13].

B. *Predictive control*

Model Based Predictive Control (MBPC) ([14]) is a control strategy based on the explicit use of a model to predict the process output over a long-range time period. A receding control horizon technique is used: only the first control signal is applied (so all the changes that take place between two control signal calculations are considered). A cost function is minimized at each sampling time. It is usually defined as a linear combination of the tracking error and the manipulated variables (the most common formulation being a quadratic cost function).

Although a non-linear model can be used for prediction, computational and robustness considerations makes the use of a linear model more adequate. Following the Generalized Predictive Controller (GPC) described in [14], a MIMO controller is described here. Considering a process with M inputs, N outputs and R measurable disturbances represented by the model:

$$A_i\left(q^{-1}\right)y_i(t) = \sum_{j=1}^{N} B_{ij}\left(q^{-1}\right)u_j(t) + \sum_{j=1}^{R} D_{ij}\left(q^{-1}\right)v_j(t) + \frac{T_i}{\Delta}\xi_i(t) \tag{2}$$

where: $i = 1, ..., M$ and A_i, B_{ij}, D_{ij} and T_i are polynomials in the q^{-1} operator, $\Delta=1-q^{-1}$ and ξ_i is white noise. The predicted future values of the controlled variables are:

$$\hat{y}_i(t+j) = \sum_{j=1}^{M}\sum_{k=1}^{j}\sigma_j g_{ij_k}\Delta u_j(t-k+j) + p_i(t+j), i = 1,\ldots,N \tag{3}$$

where g_{ij} is the step response between y_i and u_j and p_i is the free response of y_i. The coefficients σ and η take the value 1 if the corresponding input is included in the predicted output and 0 if it is not.

The control algorithm objective is the calculation of the sequence of (optimal) changes of the control variables in a control horizon Nu: $\Delta u_i(t+j)$, $j=0,..., Nu_i-1$ so that the predicted outputs $\hat{y}_i$ are as close as possible to the internal reference $r_i(t+j)$. This is translated into an optimization problem where a quadratic cost function of the tracking error and the manipulated variables is minimized, taking into account constraints on **Δu**, **u**, **y** and any other constrained variable that depends on **Δu**. This optimization problem can be stated as:

$$J = \sum_{i=1}^{N}\sum_{j=N1i}^{N2i}\eta_i\left(\gamma_i\left(\hat{y}_i(t+j)-r_i(t+j)\right)^2\right) +, \sum_{i=1}^{M}\sum_{j=0}^{Nu_i-1}\sigma\left(\beta\Delta u_i(t+j)\right)^2 \tag{4}$$

$$D_{m_i} \le \Delta u_i(t+j) \le D_{M_i}, j = 0,\ldots,N_{u_i}-1$$

$$U_{m_i} \le u_i(t+j) = u_i(t-1) + \sum_{i=0}^{j}\Delta u_i(t+j) \le U_{M_i}$$

$$L_{m_i} \le \hat{y}_i(t+j) \le L_{M_i}, j = N3_i,\ldots,N4_i \tag{5}$$

where the coefficients γ and β give the relative weight of every prediction error or change in the control variables, while the coefficients σ and η taking the value 1 or 0 allow a variable to be included in the index or excluded from it. When no constraints are considered, there exists an explicit solution of (4).

VI. CONAPA

Previous sections have described the architecture and the internal description of the system. Now, the user's interface is presented.

The tool is open; everyone can use it, although there are sections that require a password (Figure 10). There is only one web server, so only one student at a time can change the parameters of the controller that calculates MC and KA. The data acquisition area is also protected because the real system can only be accessed one user at a time.

The following subsections will describe CONAPA's capabilities and basic software engineering:

a. Data acquisition.
b. Simulation of the web server.
c. Control of the web server online.
d. Comparison of simulation and real system.
e. Setting the benchmark traffic generator parameters.

A. *Data acquisition*

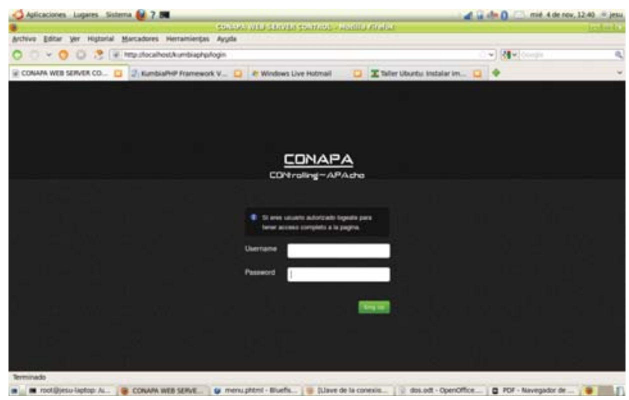

Figure 10. CONAPA's login screenshot

The user can collect data that allows the identification of a model that reflects how the real system works. As we have two inputs and two outputs, we keep constant one input and the other changes between the max and minimum value where the step duration decreases over time until 0 is reached. The procedure is repeated for the input that remained constant. This data can later be analyzed in other software such as Matlab. The period and max/min values are introduced by the user (Figure 11).

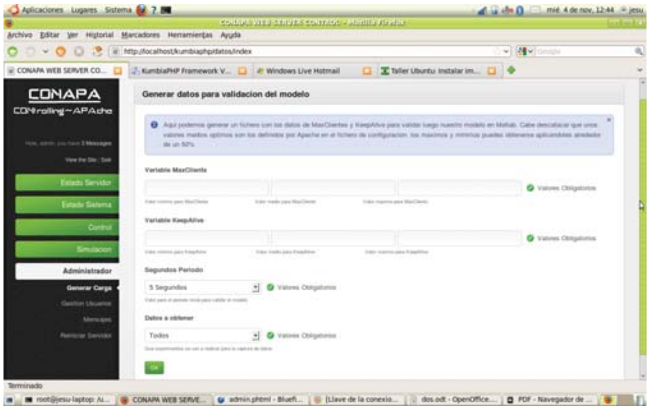

Figure 11. Setting parameters for data acquisition

Figure 12 shows the input variables (upper graphs) and the corresponding values for the outputs (lower graphs). A simple sequence diagram showing the main steps involved in the process is shown in Figure 13.

B. *Web server's simulation*

This area is open to all users. The type of controller can be selected and then the parameters (for instance, proportional, derivative and integral terms of the PID) should be entered. Each type of control has its own screen and parameters.

C. *Web server's control*

The available controllers are the same as in the previous sub-section. But, only one user can work with the real system. Each sampling time, KA, MC, MEM and CPU are read (using the socket described in Section IV) and sent to the controller.

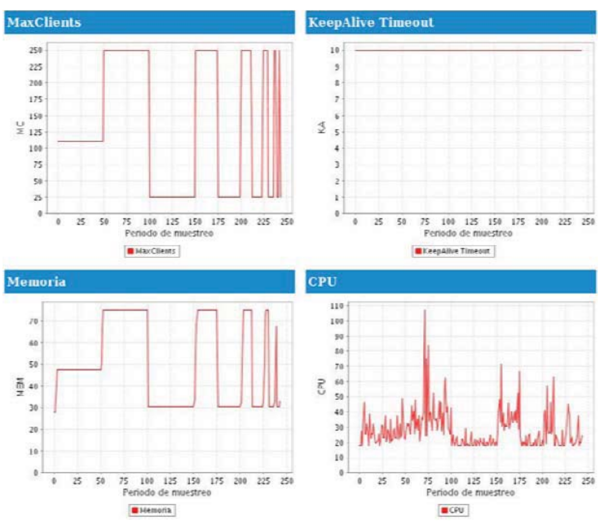

Figure 12. Data to export for identification

New values for MC and KA are calculated and sent to the server. Figure 14 shows the results of an experiment where the reference for the CPU was 5% and MEM was 40%. The controller was a PID.

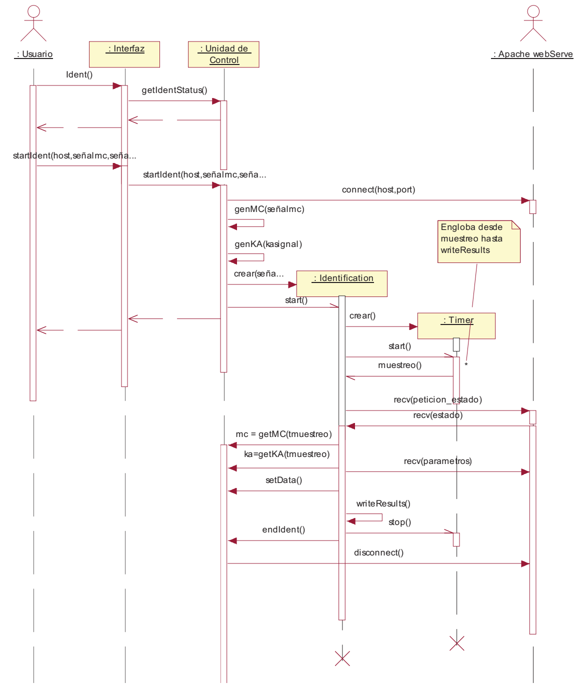

Figure 13. Sequence diagram, data acquisition

Figure 14. Real control

D. *Comparison of simulated and real system*

When this option is chosen, the real system is controlled and we apply the same tuning parameters to the simulation model. Thus, we compare whether the model and the real system have the same trends. This is quite useful if we are teaching our students the differences between simulation and the real world.

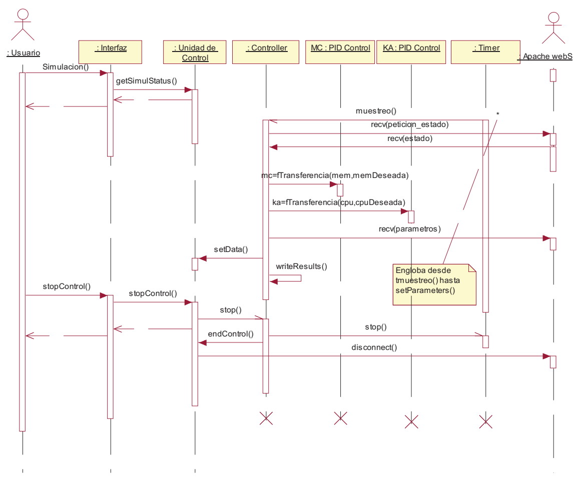

Figure 15. Simulation versus real system

Figure 15 shows the sequence diagram for this case when the controller is a PID.

E. *Setting the benchmark traffic generator parameters*

Different traffic conditions cause the behavior of the Apache web server to change. The tuning of the controller can be good for a traffic situation but not so adequate for another.

If we can define different scenarios, we can check the goodness of the controllers and the range they work in within acceptable performance.

This option is rather interesting for students because they can learn to think as a web administrator and deal with day to day situations. So, if they work administering networks in the future, they can be prepared to respond under pressure and changing network traffic loads.

VII. WHY IS CONAPA USEFUL?

It cannot be argued that there are many tools that present different components and characteristics of automatic control. There are virtual laboratories, online laboratories, add-ons to existing software: they are useful and have been developed for certain students and requirements.

CONAPA was built for students who follow courses where automatic control is not traditionally the main objective. But, if they are going to be good engineers they need a basic formation/knowledge and understanding of fundamental control ideas. If anyone studies Telecommunications or Computer Science, it is clear that they prefer networks and computers to a conventional mechanical system. It is at this point where problems arise. As stated in the introduction, most control books and applications deal with classic examples: electrical, mechanical, … So, we thought it would be interesting to present a system which these future engineers felt close to and that the tool could provide them with notions and knowledge in other valuable fields. CONAPA can be used for:

- Learning basic identification methods.
- Linear simulation.
- Controlling the Apache web server in simulation.
- Controlling the REAL Apache web server.
- Setting different traffic conditions and visualizing results: congestion, underutilization, overexploitation …

It is also useful for understanding Apache itself, how it works and how it can be modified to fulfill our necessities.

VIII. CONCLUSIONS

The paper has presented a tool that works both as a virtual and an online laboratory. The real system is a web server. Students can freely work with the simulation area, check their controllers and compare their tunings with the one that is being applied to the real system. The control of the web server is restricted because only one person at a time can change the parameters: we only have one plant and many potential users.

CONAPA is useful for those students whose degrees are not closely related to mechanical or traditional process control environments. They can see that automatic control can be applied to plants that have the same problems as these more conventional systems, but they feel more related to them.

The paper has given details on how to modify Apache's source code because there is little information about it and this was the hardest part of the work. In the future, we plan to migrate to a Windows operating system and to a higher Apache release.

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Session 09B Area 4: Active Learning - Collaborative learning

Retaining and Retraining: An Innovative Approach to Educating Engineers in a Changing Economy

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Active Learning in Telecommunication Engineering: A case study

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Reviews and Findings on Implementing Active Learning in a Large Class Environment

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Retaining and Retraining:

An Innovative Approach to Educating Engineers in a Changing Economy

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***Abstract*— Changing economic and technological conditions require that talented and experienced engineers adapt and update their engineering skills. Communities support education and retraining in order to retain the human talent. This paper describes an innovative approach to helping engineers overcome barriers to career transitions, which incorporates career and personal development, an engineering skills refresher, a semester-long course at a top-tier engineering school, and an internship at a company in a high-growth sector.**

We describe the motivation for embarking on a career re-engineering program. A large percentage of the engineering population in the Austin community is engaged in semiconductor design and manufacturing, an industry in decline. In order to harness the collective skills and talents of engineers in the semiconductor industry and to redirect those skills, the Center for Lifelong Engineering Education provides training to help engineers to re-tool their skills for growth industries.

We describe success factors for a career re-engineering program, including (1) the engagement with multiple stakeholders: a university engineering faculty, community development organizations such as workforce commissions, companies in high-growth sectors, the university career counseling center, and governmental agencies; (2) the acquisition of funding to help support engineers as they embark on a retraining curriculum; and (3) the application process and selection criteria.

We describe the curriculum, including an initial orientation and assessment program; the selection of appropriate and available fall-semester engineering classes in fields such as biotechnology, nanotechnology, and environmental sciences; monthly workshops designed to improve communication, presentation, adaptability, and networking skills; weekly small-team meetings designed to keep participants accountable; regular meetings with individual mentors; and a spring-semester internship with a firm in a high-growth sector.

Programs to help retrain engineers and to retain engineering talent within a society are critical to community sustainability and growth.

Keywords- engineering professional development; continuing education; retraining; community development.

I. INTRODUCTION

Economic sustainability requires communities to adapt to changing environmental conditions. At both the macro-level and the micro-level, communities that fail to adapt to environmental changes decline. Programs to help retrain engineers and to retain engineering talent within a society are critical to community sustainability and growth.

II. HISTORICAL PERSPECTIVE

History provides us with examples of communities, both broadly and narrowly defined, in which engineering expertise provided the basis for economic growth, and in which the failure of the community to adapt to changing conditions and build new technological expertise led to economic decline.

A. Portugal

Navigational technology enabled Portugal to become a world power. In the early fourteenth century shipbuilders moved from a heavy shipbuilding technology, using overlapped wooden planks to keep water out of the vessel, to a lighter construction with a simple skeleton and caulking, the caravel construction. The caravels were larger, lighter, cheaper to sail and more seaworthy than their predecessors [1]. Mathematicians developed techniques for estimating distances from port to port, dead reckoning. Navigators developed port books or "*portolanos*" which allowed them to plot their voyages. By the fourteenth century, the compass was in use in Mediterranean allowing sailors to navigate even in cloudy weather [2].

In the fifteenth century, Prince Henry of Portugal (Henry the Navigator) launched several expeditions, apparently for both religious crusades and commercial reasons [3][4]. Henry the Navigator's nautical school helped prepare Vasco de Gama, who, at the close of the fifteenth century and early sixteenth century, rounded Africa and sailed to India, establishing Portuguese colonies around the coast of Africa, and creating important trade routes.

Portuguese navigational skills made the Portuguese rise to world power possible. When navigational skills became commonplace and less of a competitive advantage, Portugal did not sustain its dominant position. By the seventeenth century, the skill giving competitive advantage was the ability to manage far-flung empires, new forms of legal and financial risk-sharing (early insurance companies) and commercial trading companies.

And finally the competitive advantage afforded by the Industrial Revolution in the nineteenth century was slow to take hold in Portugal [5], giving a competitive advantage to England and France. Portugal fell from its position of world domination and suffered economic decline.

B. The Steel Industry

The United States turned to steel manufacturing during the depression of the 1890s. The industry flourished, and steel was the archetype and innovator of American commerce, dominating all competitors, nationally and internationally. Used for soup cans, automobiles, the cabling for the Golden Gate Bridge, steel production provided jobs for thousands of Americans. Early engineering advances fell aside to the later short-sightedness of upper management. Even as late as the 1990s leaders at Bethlehem Steel refused to adapt their traditional methods despite advances from "mini-mill" steel companies as well as the resurgence and development of alternative materials (aluminum and plastics) [6].

This failure by upper management to respond proactively to the influx of cheaper, foreign steel and remain entrenched in historical methodologies led to the loss of thousands of jobs and dramatically impacted a way of life for many Americans.

C. Digital Equipment Corporation

At the micro-level, the level of an individual company, the story of the rise and fall of Digital Equipment Corporation, is telling. DEC's engineering strength, culture of innovation and its dominance in the mini-computer market allowed it to rise to be second only to IBM in the computer industry, with annual revenues of $14 billion. DEC's decline, however, was precipitous, falling from market dominance to its demise in less than ten years.

The reasons for DEC's failure involve a complex array of issues. The obvious one is that DEC failed to adapt to the shift in the market, away from minicomputers to personal computers. Less apparent but equally powerful reasons involve the DEC culture and its focus on innovation and consensus. When the market shifted to one with far lower profit margins, the engineering skill that bestowed competitive advantage changed from expertise in innovation to capability in efficiency, cost controls and managing to very tight budgets.

Microsoft, Dell and Intel have de-bunked the myth that the best technology "wins." At different intervals, DEC had the best computer, best processor, and best search engine. DEC missed the market window by being too late (processor) or too early (search engine). Management's inability to seriously consider the threat of competition and develop an agile response led to the company's ultimate downfall. [7]

According to [8], "dealing with the business problems requires switching from the 'fun' of innovation and growth to the 'hard work' of creating a business strategy process, of becoming cost conscious, of changing organizational routines toward efficiency…, of modifying the basic processes in engineering and manufacturing to respond to changing technology."

The story of DEC is a chronicle of a failure to adapt to a changed environment.

III. Changes in the Semiconductor Industry

The global electronics industry suffered a significant decline in 2009, and the Austin technology community has suffered a 24% decline in employment [9]. Industry observers do not expect that the region will regain these jobs. Dell, Spansion, AMD, Freescale Semiconductor, Samsung and Applied Materials have reduced their manufacturing employment from approximately 40,000 to approximately 20,000. Table 1 illustrates the decline in the manufacturing industry in Austin.

The decline in technology jobs in the Austin region disrupts the careers of engineers, reduces the value of manufacturing plants, reduces the property tax revenue, and disrupts the ecosystem of suppliers and service companies that provided parts and services to the semiconductor companies.

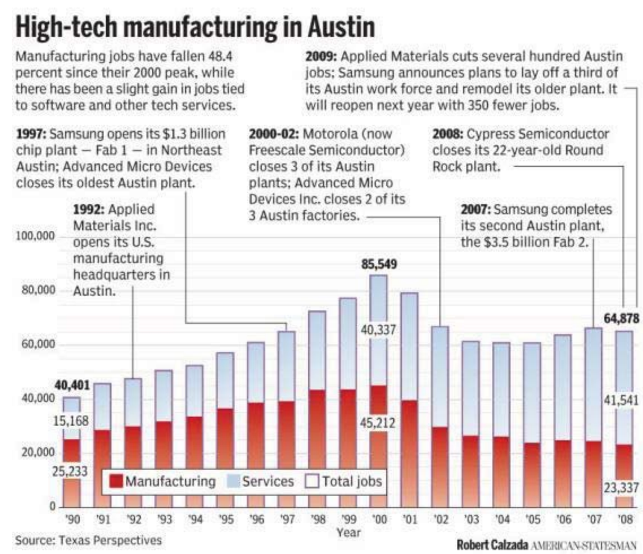
IV. Possible Scenarios

Given the loss of employment in the semiconductor manufacturing industry, what are some of the possible scenarios for the community?

A. Brain drain

In one scenario, engineers leave to work in other communities where their skills are still valued. However, given that the semiconductor manufacturing industry jobs are now primarily in Asia, the opportunity for relocating is small.

Table 1: High Tech Manufacturing in Austin [9]



B. Community decline

In a second scenario, engineers take positions which do not utilize their problem-solving and engineering skills or they remain unemployed. This is the primary current situation. Engineers are currently receiving unemployment benefits while looking for new employment.

C. Revitalization

In a third scenario, engineers receive training in a growth area and help to build new industries, applying their problem-solving skills to new problem domains. With training in entrepreneurial skills, they are able to build new firms and revitalize the economy.

This scenario happens at the individual level with great regularity. Engineers acquire certain skills in their college training, but within a few years, those skills are stale; technology has advanced. Many engineers recognize the need for regular skill enhancement and seek out training opportunities, either through their firms or on their own. Typically, these are technical skills. Engineers who want sustainable careers see the need for frequent skill enhancement.

But faced with a massive industry decline, technical skill acquisition alone is inadequate. In order to help rebuild an economy, the engineers' problem-solving and engineering skills need to be supplemented with leadership, communication, and negotiation skills.

V. Responding to a Changed Environment

How can a community, whether it is a nation, a region, a city or a firm, respond to a change in its technical and economic environment?

First, that community must recognize that if it fails to support the re-tooling of its talent, it will go into certain decline.

Second, it must recognize that it needs to support retraining its engineers to acquire skills in areas of potential growth and skills in leadership in order to help build new industries. Such retraining is necessary in order to retain the engineering talent within the community.

Applied Materials, a leading capital equipment producer serving the semiconductor industry and based in the Silicon Valley, recognizes the risks to its business and is attempting to move into the growth industry of manufacturing solar equipment. This is the sort of adaptability that can revitalize a community, in this case the community of one firm. So far, however, Applied Materials has not found adequate demand for solar equipment in the United States [10].

The Center for Lifelong Engineering Education at the University of Texas at Austin's Cockrell School of Engineering currently offers training to engineers in Aerospace Engineering, Biomedical Engineering, Chemical Engineering, Civil Engineering, Electrical and Computer Engineering, Energy and Environmental Engineering, Engineering Ethics, Engineering Finance, Engineering Leadership, Mechanical Engineering, Petroleum Engineering and Software Engineering. These programs fulfill the need for the incremental training that helps individual engineers enhance their skills in order to sustain their careers. This incremental training, while critical for engineers to sustain their careers, is still not adequate to meet the needs of revitalizing an entire community.

VI. A Program for Retraining and Retaining

In order for the Austin community to sustain its economic viability, we propose a program to provide a significant retooling of the current engineers. The program, still in the planning stages, includes several elements.

A. A well-defined application, selection and matching process

In order for this program to be successful, it must have a well-defined application, selection and matching process. Engineers admitted to the program must have talent and intelligence as well as motivation to learn the concepts of a new domain. In short, they must be adaptable.

Participants accepted into the program attend a week-long orientation program. Initial assessments help match individuals with appropriate fields of study and point them in the direction of appropriate course work. Participants assess their professional strengths and create plans to build their skills and networks. Participants attend workshops on communication and presentation skills.

Video snippets of professors and their courses provide the engineers with a sample of what might be of interest to them.

B. Fall semester engineering coursework

Once admitted to the program, participants enroll in one fall semester course. They select the course that will help them establish expertise in a new field.

The coursework will be in growth technology fields, such as power engineering, battery engineering, and biotechnology.

C. Monthly workshops

During the orientation and fall semester, participants attend monthly workshops on communication skills and negotiation skills. They learn how to present a project idea and gain acceptance; how to present themselves at meetings and interviews; about gender and cultural differences and how to communicate effectively will all. They learn presentation skills, including videotaping, critiquing and practicing. They learn to understand their audience and speak in ways that the audience can hear. They learn leadership skills and entrepreneurial skills. They learn practical negotiation skills and how to expand the negotiation space.

D. A five-month and ten-month option

Some engineers find that a five-month program including assessments, workshops and one semester of academic instruction will be adequate to their needs. Others benefit from a second semester (the ten-month option) which includes a five-month internship at a local firm in a high-growth sector.

E. *Small teams*

Once admitted to the program, participants join small teams of three to five individuals. These teams meet weekly for accountability, encouragement and networking.

F. *Mentoring*

Once admitted to the program, participants begin working with a mentor, a senior member of the engineering community who can provide career guidance and advice.

G. *Broad community support*

In order for this program to be successful, it must have the support of the broader community, including the university, the engineering faculty, the Chamber of Commerce, local industry, venture capitalists, workforce commissions and career counselors.

H. *Support from the university*

Support from the university is critical, because it must be willing to accept non-traditional students into a program that crosses the boundary between academic degree courses and continuing education programs. If a university sees its role as a research institution only, it does not value community revitalization, nor does it see itself as a resource in an effort to revitalize a community.

I. *Support from the university faculty*

Support from university faculty is critical because the faculty must be willing to accept non-traditional students into their classes. Engineers in need of retraining are often 20 years out of college. They may have exceptional experience, but lack specific courses considered to be pre-requisites for certain classes. The engineering faculty has to work with the program administrators to ensure that the engineers are academically equipped to succeed in the courses while not restricting the admissions onerously.

J. *Support from local industry*

In order to provide post-training internships, the program requires support from the Chamber of Commerce and local industry. The Chamber benefits by retaining the community's engineering talent. Local industry benefits through the increased and better-trained talent pool. They will find excellent engineers who have taken the initiative to acquire new engineering skills.

K. *Venture capitalist support*

Venture capitalists support the program by coaching engineers with ideas to become successful entrepreneurs. Building new industries is notoriously risky, and novices need senior guidance.

L. *Public workforce commission support*

Support from the Workforce Commission provides funding for skills development for engineers.

M. *Career counselor support*

University career counselors provide assessments and advice to engineers entering the program.

N. *Financial support*

In order for this program to be successful, it must have the support of funding agencies, such as the National Science Foundation and the Workforce Commission. Unemployed engineers are unlikely to be in a position to fund their training. Moreover, this program is intended to benefit the community, whether it is seen as a local community, a region or a country, by retaining the talents of skilled engineers.

VII. Results from Preliminary Programs

The Center for Lifelong Engineering Education has provided training in leadership for engineering managers and has results of the usefulness of that training for sustaining careers, primarily in software engineering. Results from the Engineering Leadership Institute can be used to determine likely usefulness of various kinds of career and personal development training for engineers seeking to revitalize their careers through a retraining effort. Table 2 summarizes the usage of the skills acquired in this program.

A. *Communications skills*

Ninety-four percent of students who have taken the Engineering Leadership Institute's Communications Skills workshop report that they are using it extensively to support their careers, and 100% report that they are using the materials they learned in this program.

The workshop includes training in tailoring communications to your audience, presenting ideas with impact, understanding gender and cultural communication differences, listening to understand and delivering bad news.

B. *Skills for dealing with different personality types*

Eighty-two percent of students who have taken the Engineering Leadership Institute's workshop in Dealing with Different Personality Types and How to Work More Effectively With Them, using the Myers-Briggs Type Indicator, report that they are using it extensively to support their careers, and an additional twelve percent report that they are using the materials they learned in this program. Six percent of the program participants report that they are not making use of this training.

C. *Skills for managing up*

Seventy-one percent of students who have taken the Engineering Leadership Institute's workshop in Managing Up: What You Boss Needs from You, report that they are using the skills extensively to support their careers, and an additional twenty-nine percent report that they are using the materials they learned in this program.

D. Problem-solving skills

Seventy-one percent of students who have taken the Engineering Leadership Institute's workshop in Problem-Solving Skills report that they are using the skills extensively to support their careers, and an additional twenty-nine percent report that they are using the materials they learned in this program.

E. Skills for dealing with difficult people

Sixty-three percent of students who have taken the Engineering Leadership Institute's workshop in Dealing with Difficult People report that they are using the skills extensively to support their careers, and an additional thirty-eight percent report that they are using the materials they learned in this program. All of the students were making use of these skills in some way.

F. Risk management skills

Fifty-six percent of the Engineering Leadership Institute students reported that they were making extensive use of the risk management skills they learned in the program, and an additional forty-four percent reported that they were using the risk management skills in some way. .

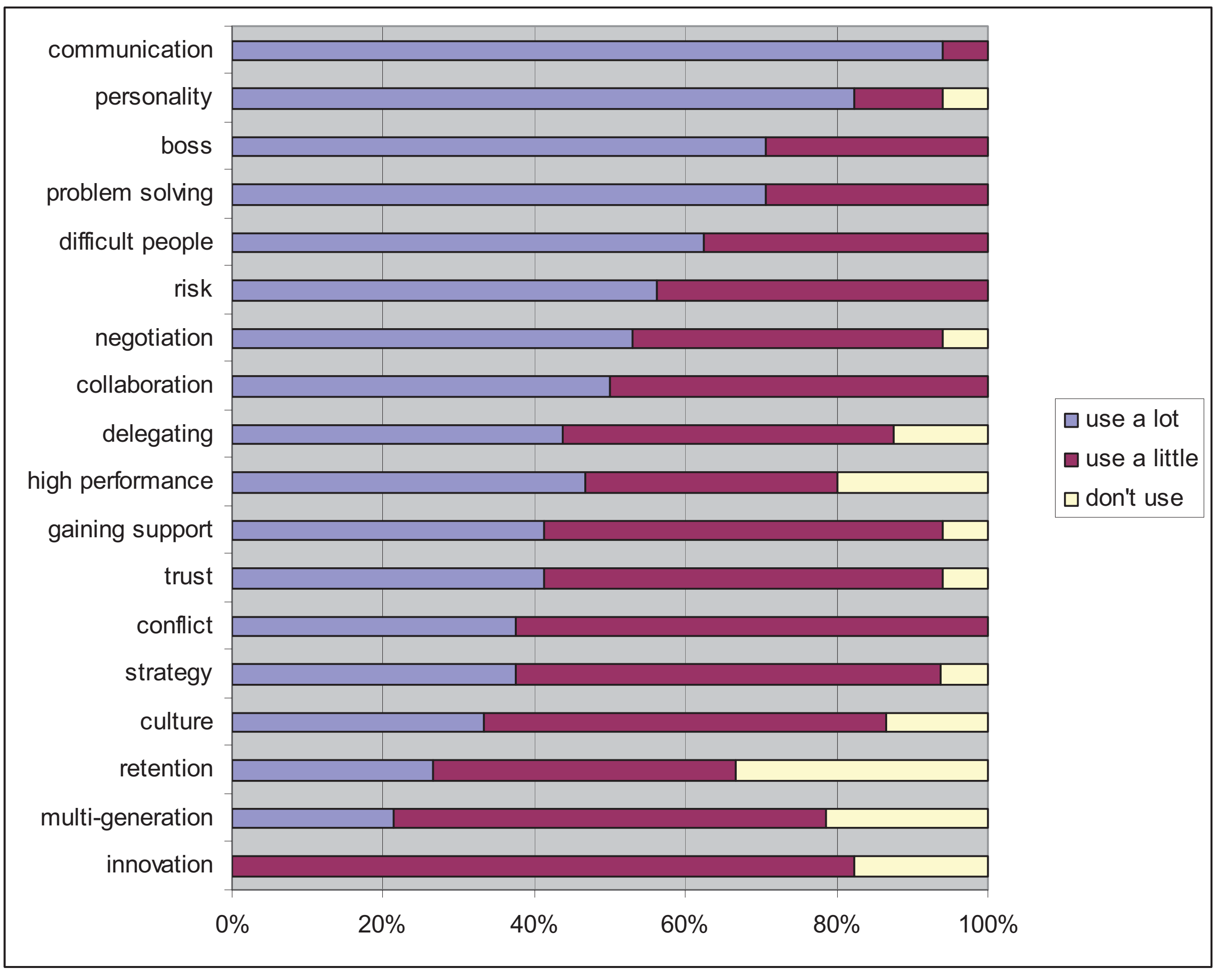
G. Practical negotiation skills

Fifty-three percent of the Engineering Leadership Institute students reported that they were making extensive use of the negotiation skills they learned in the program, and an additional forty-one percent reported that they were using the negotiation skills in some way. Six percent reported that they were not making use of the negotiation skills.

H. Collaboration skills

Forty-seven percent of the Engineering Leadership Institute students reported that they were making extensive use of the collaboration skills they learned in the program, and an additional forty-seven percent reported that they were using the collaboration skills in some way.

Table 2: Percentage Usage of Leadership Skills



I. Delegation skills

Forty-four percent of the Engineering Leadership Institute students reported that they were making extensive use of the delegation skills they learned in the program, and an additional forty-four percent reported that they were using the collaboration skills in some way. Thirteen percent indicated that they were not yet using these skills, primarily because they are not in leadership or management roles yet.

J. Skills for building high performance teams

Forty-four percent of the Engineering Leadership Institute students reported that they were making extensive use of the skills for building high-performance teams they learned in the program, and an additional thirty-one percent reported that they were using the skills in some way. Nineteen percent reported not yet using these skills, primarily because they were not yet leading or building teams.

K. Other skills

Sixty-three percent of the participants were using skills to attract and retain good employees. And more than three-quarters of the participants were using the remainder of the skills taught in the Engineering Leadership Institute, including building trust, conflict management, strategic planning, developing a culture of success, managing a multi-generational and multi-cultural workforce and innovation management.

VIII. Revitalizing a Community

Data from the Engineering Leadership Institute's participants validates the usefulness of the career and personal development skills workshops for enhancing and revitalizing individual careers, and will be useful in building a broader program. Many of the engineers in the program have provided testimonials as to their individual career growth as well as their contributions to their sponsoring company. Most significant: engineers who were technically proficient and had been moved into management based on their technical proficiency felt they were no longer immersed in their area of expertise. This program taught them to balance their technical growth with their leadership skills, thereby expanding their comfort and competency in leading technical projects and/or teams.

The program defined can be used in any community with a top level engineering university. It is customized to the group needs, providing just-in-time training that is immediately applicable. As a result, engineers are able to bridge the gap between their technical training and the demands of managing projects and people. We have defined it in such a way that the community sees the benefit from the program and sees that ongoing efforts to retrain and retain their engineering talent are crucial to economic viability.

Why is this program innovative? Most professional development or continuing education programs for engineers focus on improving on the base of established engineering skills, or on adding people skills to the existing engineering skills. This program is innovative because of its systemic approach; the individual's skills are enhanced within the context of the economic conditions, and they are enhanced in both the hard skills (new technologies) and the soft skills such as communication, negotiation, and proficiency in human interactions.

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Active Learning in Telecommunication Engineering: A case study

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Abstract—**Bologna process establishes a big change from class-based lessons to active learning. This process shifts the focus from instructor-centered teaching to student-centered active learning, putting the student in the centre of his own learning. This paper presents a case study of active learning in Telecommunication Engineering at Rey Juan Carlos University. Specifically, it presents the experience of different active learning activities in Object Oriented Programming (OOP) subject, where students developed their initiative and critical thinking. This paper presents both global data (i.e. number of students, their background, description of the theoretical, practical and new active learning activities) and specific data (i.e. scores obtained in the different activities proposed, time spent in each learning activity, participation in the learning activities, students' interactions, etc.). Furthermore, the comments of the own students about their personal experience with these new active learning activities are included.**

Keywords: Engineering Education; Collaborative Work; Active Learning.

I. INTRODUCTION

Bologna process establishes a big change from class-based lessons to active learning. This process shifts the focus from instructor-centered teaching to student-centered active learning, putting the student in the centre of his own learning. Lifelong learning has been recognized as an essential element of the European Higher Education Area since the Ministers met in Prague in 2001 [1]. The '*Prague Communiqué*' signals that in a Europe built on a knowledge-based society and economy, lifelong learning strategies are necessary to face the challenges of competitiveness and the use of new technologies, and to improve social cohesion, equal opportunities and quality of life. Since then, there has been growing awareness of the need to embed lifelong learning within higher education.

This new educational paradigm requires other methodologies that enhance the active role of the student, his initiative and critical thinking. There are several pedagogical theories related to active learning such as '*Sociocultural Theory*' or '*Constructivism Theory*'. On the one hand, '*Sociocultural Theory*' [2] emphasizes that the human intelligence originates our society or culture, and that individual cognitive gain mainly occurs through the interaction with the social environment and the knowledge internalization. Knowledge is constructed and discovered by students and transformed into concepts, which students can relate [3]. Learning consists of active participation by the student versus passive acceptance of information presented by an expert lecturer. Students are actively constructing their own individual knowledge, and learn how to understand and appreciate different perspectives through a dialogue with their peers. On the other hand, '*Constructivism Theory*' [4] states that knowledge is not a fixed object but an object continuously evolving. Knowledge is constructed by the individual through his own experience of that object. Learners have to assume the responsibilities related to their own learning. They have to develop abilities to monitor and direct their own learning and performance. When people work collaboratively in an activity, they can see a problem from different perspectives and are able to negotiate, to generate meanings and solutions through shared understanding.

In both pedagogical theories, students collaborate with others in order to promote the active learning and the interaction between peers. The origins of collaboration activities are based on the real world, given that everybody is member of several groups. In our daily activity we are continuously interacting inside groups: in the family life, with our friends, in our work, etc. Our personal identity stems from the way of perceiving and of treating with other members of the groups. Within the group we learn to behave, to think, to educate ourselves and to learn from our interaction with the rest of the members of the group [5].

There are several research works performed at different fields that they evidence the goodness and the limits of active learning. In [6], it is found that there is broad but uneven support for the core elements of active, collaborative, cooperative and problem-based learning. This paper also shows that a unique technique is inadequate to achieve a better learning. Felder et al. [7] give some instructional methods to support these new paradigms, in order to teach more about "real-world" engineering design and operations.

Face-to-face collaborative learning has been applied in traditional classrooms since the 70s, although most of theoretical studies related with it date back of the 80s [8]. In these years different methods and studies arose trying to apply collaborative learning technologies to students of diverse ages and levels. These experiences pointed out that the learning process is not only the own identification of the knowledge finally acquired, but also includes the explanations that are provided in order to identify which information is missed, the inconsistencies that are detected, what needs to be clarified or is discussed from different points of view by different members of the group [2].

In this one sense, collaborative learning is a social activity that involves a students' community in which some knowledge is shared and other new one is acquired (knowledge construction) [4] [9]. It means that, apart from the solution itself, it is also important the process that has made it possible to reach that solution. Then, the goal of collaborative learning is that the students were actively involved in the exploratory learning process working together [10].

Collaboration has great benefits such as to promote the cooperation, the interaction and the familiarity among students and teachers. Moreover, from the computer scientists' point of view, collaborative environments facilitate the development of reasoning skills [11] such as making ideas explicit, arguing, interacting with other students to build a common solution, and so on [12]. There are some experiences that demonstrate that the student's motivation, participation and auto esteem increase when they obtain good results in the accomplished collaborative activities.

Also, there is another fact that has to be taken into, and has to with the huge number of students that have difficulties to express their opinions in public. In traditional classrooms when the teacher asks to one student, the focus of the attention is centered in him or her, while in collaborative environments the focus of attention is distributed among the members of a group. Therefore, collaborative learning creates a safe environment in which students can express and explore their own ideas without fear to failure or critics, helping to develop their skills of communication. The student companions can make constructive critics to the different ideas that are proposed [13], while the teacher can evaluate the learning process as a whole (the reasoning process), not only the final solution of the activity. In this sense, some studies on cooperative learning among students of different ethnics state that their communication skills have been clearly increased [8], due to the fact that students have been actively involved in the learning process, being able to understand the differences, and helping them to learn how to solve the social problems that could arise among them.

Collaborative workgroups should be constituted by the minimal number of people need to perform the work in a effective way. Although collaborative learning groups typically are constituted by two to four persons, the basic rule is: 'the smaller the better' [5]. However, there is not an ideal size for collaborative learning group. The group's productivity is determined by how well the members work together. Usually, homogeneous groups can achieve better specific aims, however, when students with different abilities, experiences and interests are combined (heterogeneous groups), they can obtain more advantages than homogeneous groups. In addition, if the students are allowed to organize themselves, they usually create homogeneous groups, and if the teacher is responsible for making up the groups, he or she selects homogeneous or heterogeneous groups according with his/her personal criteria [14].

To sum up, Bologna process motivates a teaching change where the student was the responsible to own learning process in order to promote the lifelong learning. Collaborative learning between peers has been used during years with this purpose. Furthermore, it contributes to development of personal and social skills such as critical thinking, teamwork, communication abilities and conflict resolution between others.

In this new frame, a combination of different individual and collaborative learning activities play an important role in providing new contexts and possibilities in order to develop these skills. This paper presents a case study of active learning in Telecommunication Engineering at Rey Juan Carlos University. Specifically, it presents the experience of active learning in Object Oriented Programming (OOP) subject.

This paper is structured in several sections. Section 2 describes the general characteristics of the case study including a description of the subject and the characteristics of the new active learning activities proposed to students in order to improve their own learning. In section 3, the global results of this case study and the scores of the new learning activities are shown. Finally, conclusions are presented.

II. THE CASE STUDY

Object Oriented Programming is an optional subject at third year of Telecommunication Engineering at Rey Juan Carlos University. This subject is structured in two main parts: principles of Object Oriented Design using UML and, basic concepts of OOP and applications in Java.

Although all the students belong to Telecommunication Engineering, their profile is different. On the one hand, some students have already studied other subject where they have programmed in Java language. They know some aspects of OOP (concepts of class, object, encapsulation, polymorphism, inheritance, etc.). On the other hand, other students have programmed in other structured programming languages but not in Java. These last students have not previous knowledge of Object Oriented Programming. Students of both profiles have not previous knowledge about object oriented design.

In past years, this subject was structured in theoretical and practical sessions. In theoretical classes, the teacher explained concepts, showed examples of the concepts and proposed exercises to students for solving in the classroom. In practical sessions, students developed Java applications in order to put in practice the theoretical concepts. With this model, students were already participated of their own learning process in an active way.

However, during the 2008-2009 academic year, the teachers of this subject thought that could be useful to include learning activities where students develop their initiative and critical thinking and promote the interaction between students with different background. With this goal, some practical exercises related to object oriented design; a collaborative activity with a public oral presentation; and new practical sessions were proposed to students. Each new activity is explained in the next sub-sections.

A. PACS ('Programming Assignment Correction System')

Teachers of OOP subject wanted students would acquire deep knowledge of "object oriented design" topic and participate in an active way on their own learning process. Furthermore, they wanted that students would develop some personal and social skills such as critical thinking and communication abilities.

In this way, the teachers decided to combine theoretical classes with some practical exercises related to object oriented design. The whole 'OO Design' teaching process can be observed in Figure 1.

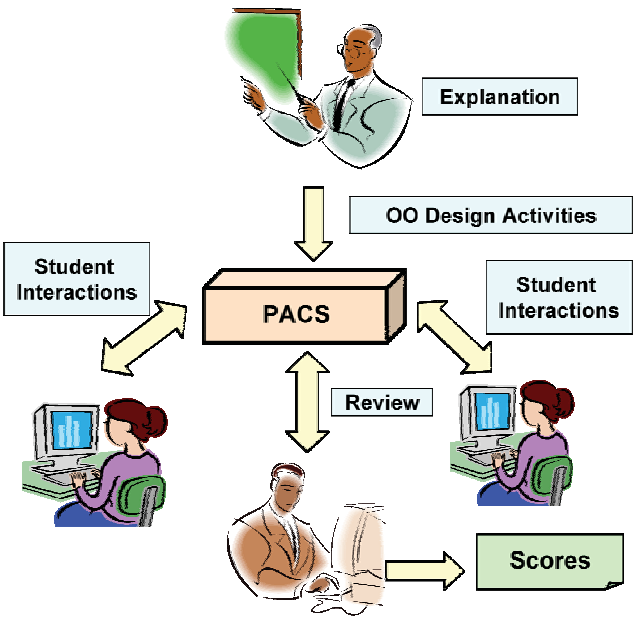

Figure 1. OO Design Teaching Process using PACS.

Firstly, 'Object Oriented Design' concept and the different types of UML diagrams were explained by the teacher in the classroom. Furthermore, students could observe design examples of different OOP applications and accomplish small exercises in the classroom related to every type of UML diagrams.

When theoretical bases had been explained, the teacher proposed a set of practical exercises related to OO design to the students. These exercises should be performed individually by each student. Once students finished their design exercises, they might send their solutions to PACS ('*Programming Assignment Correction System*'). This system is a CSCL ('*Computer Supported Collaborative Learning*') tool developed by Manuel Freire at Universidad Autónoma de Madrid [15]. Students uploaded their solution to this system and then, they adopted the teacher role. They should correct the designs of two classmates corresponding to the same set of exercises or a similar set.

Before using PACS, teachers provide an explanation of this system, how to use it, and a guide with the criteria in order to correct the solutions of their partners. This guide includes the following instructions:

- If the solution of his partner was perfect, the student should try to obtain alternative solution designs in order to give feedback to his partner. Furthermore, he should compare the solution of his partner with his own solution and then, analyze if he did mistakes or if he has misconceptions. If a student would realize he has made errors or he had misconceptions, he should think how to solve them.
- If the solution has mistakes, the student might detect them, explain them and provide solutions.

Furthermore, teachers explained that when they uploaded the correction to the partner solution, they would receive comments about their own correction. The system allows the interaction between students and peer-to-peer collaboration. In this way, if a student is not agreed the correction of their classmates, he could comment their doubts and discuss with them. A student can discuss with his reviewers and with his partners whom he have evaluated their designs.

The figure 2 presents a screenshot with the comments of two students regarding to a certain OO design using PACS. It presents a review accomplished by Víctor and an answer of his partner, María Angeles. They talk about the state diagram of a vending machine. They are discussing the correct solution for this problem. Víctor provides a correction to María Angeles. However, María Angeles is not agreed with some aspects of the Víctor's correction. She comments her doubts arguing the problematic aspects.

An example of a summary with the score given by a student with the teacher role to the solution of his partner is presented in figure 3. The students should assign two scores. The first one indicates if it is possible to improve the solution uploaded. The second score captures if the design of the problem proposed is right or not.

For each student, the final score of this activity is calculated taking into account the own solution of the student (40% of the final score) and the corrections performed to the exercises of his partners (60% of the final score). As it can be seen, the accomplishment of good corrections was considered more important than the own solutions. It was owing to the fact that some students did not take the correction seriously in previous experiences with this system. For this reason, teachers decided to attach more importance to the correction process. The maximum score is obtained when a student has an own good solution to the set of design problems and he corrects the exercises of his classmates in a critical way, as he was the real teacher of the OOP subject (giving feedback such as explanations of the mistakes and possible solutions, or alternative ways to solve the same problem).

El 2009.04.02-18:59:56, VICTOR escribió

Diagrama de Estados 2 responder

Creo que en este ejercicio has entendido mal el concepto de estado ya que lo que marcas como estados tienen nombre de acciones (IntroducirDinero, ComprobarLata, DarRefresco, etc) y algunos eventos tienen nombre de comprobaciones booleanas, según lo entiendo yo. Sin embargo, haciendo un esfuerzo por entender esto como acciones, yo modificaría algunas condiciones como, por ejemplo, las condiciones ifvacio e ifnotvacio que habría que ponerlas como [haylatas] y [¡haylatas] ya que las condiciones en estos diagramas no se ponen con if. Dependiendo de la interpretación del funcionamiento se podrían quitar los estados finales, y redirigirlos al principio, ya que una máquina de refrescos no se apaga cuando se expende una lata. Lo que yo hubiera hecho, descrito un poco por encima, es lo siguiente: - Tendría 3 estados (Espera, EsperaPeticionLata, Comprobacion) - De espera pasaríamos a EsperaPeticionLata cuando se produzca el evento IntroducirDinero(c) y aumentaríamos una variable dinero. Tambien podríamos ir a Comprobacion si pulsaran uno de los botones de lata. - Es EsperaPeticionLata podríamos ir al mismo estado si siguen introduciendo monedas o a otro si piden la lata. - En comprobación iríamos siempre a espera pero con diferentes eventos (expenderlata[dinero>=valorlata && haylata], precioIns[dinero<valorlata], latains[¡haylata]) Nota Diseño: 0.7 Nota Mejora: 0.5

El 2009.04.02-19:51:54, MARIA ANGELES escribió

Re: Diagrama de Estados 2 responder

En este caso no estoy de acuerdo contigo, los estados es cierto que los he llamado como acciones, digamos que tu EsperaPeticioLata yo la tengo dividido en dos estados CompruebaPrecioLata e IntroducirDinero. Si que me falta una transición al mismo estado "IntroducirDinero" y que vaya aumentamdo una variable dinero, eso se me ha escapado. Digamos que en realidad una vez que "crees" que has introducido el dinero siempre le das al boton del refresco por eso mi transición al estado "ComprobarLata" (en tal caso tambien deberia haberse hecho una transicion a DevolverDinero o algo parecido ya que no se va a quedar la maquina con el dinero si no hay lata....pero bueno jeje) y despues va a comprobar que se ha metido el dinero correcto con respecto a la lata que se ha elegido "Compruebo precioLata" . Si no es correcto el dinero la maquina vuelve al estado en que pide dinero y muestra un mensaje "Introduce Dinero".

Figure 2. Example of the interaction between students using PACS

Revisión EjerciciosDiseñoUnico21

Estado de la revisión

Esta revisión se refiere a una práctica entregada por la pareja **Unico21:** el **2009.03.24-22:53:44** (-14h 6m) La revisión está **cerrada**. Las revisiones, una vez cerradas, ya no se pueden cambiar (pero si comentar). Una vez cerrada, una revision puede, a su vez, ser revisada por un profesor.

Puedes descargar una versión de la entrega que estás revisando. También puedes ver el código en tu navegador.

Como eres un profesor, puedes saltar a las páginas de estado individuales de los miembros de esta pareja

Notas de la entrega

Nota (entre 0 y 10)	Criterio
8,00	**mejora** - Mejoras: Se evaluara si es posible realizar mejoras sobre el diseño propuesto
6,90	**diseno** - Diseño: Se evaluara si es correcto el diseño del ejercicios

mejora * .3 + diseno * .7 = **7,23**

Reabrir

Figure 3. Example of the summary of the review from a student to other

B. Collaborative work and oral public presentation

The main goal of this activity was to promote the collaborative work, the active and autonomous learning and the development of communication skills. This activity was proposed to students at the end of the year. The teachers suggested a list of topics related to theoretical concepts explained before to students in the classroom. Students should organize themselves in workgroups. Then, they should choose a topic from the following list in order to study the topic selected and perform the collaborative work:

a) Relationships between OO design diagrams and their implementation in Java

b) JavaMail

c) Java and mobile devices

d) Distributed Java programming with RMI

e) Java and XML files

f) Database access with Java

g) Servlets and JSP

h) Regular expressions in Java

i) Dates, calendars and formats in Java

j) Creational design pattern: Factory, Singleton

The number of students who constituted the collaborative workgroup depended on the complexity of the topic selected. After students chose the topic, they have to do work on the assigned tasks. Firstly, they should find information of the topic selected, study this information and understand the basic aspects for this topic. Then, they should do a PowerPoint presentation of the work. At least, this presentation should include: i) a brief introduction to the topic selected presenting the general aspects, the most relevant features, advantages, problems, etc; ii) easy examples related to this topic; iii) an exercise for proposing to the rest of the classroom, iv) the solution to the previous exercise, and v) a brief bibliography.

At the end of the year, one person of the group who would be chosen randomly by the teachers would present the work to their classmates.

The score for this activity took into account the contents of the PowerPoint presentation (inclusion of general aspects, descriptive examples, well-structured exercises and correct solution), the design of the presentation (clarity, structured information, etc.), and finally, the oral presentation accomplished (clarity when they were explaining the main ideas, time spent, etc.). All the members of the same workgroup had the same mark taking into account the previous criteria. This activity works the knowledge, the comprehension and the application level of Bloom's taxonomy [16].

Students performed high quality presentations, explained the general aspects for this topic in a clear and concise way. They were able to extract the significant information for each topic selected, to present relevant examples and to propose representative exercises to the rest of their classmates.

C. New practical programming sessions

In previous years, students performed practical programming sessions where they practiced the concepts explained in theoretical classes. This year, the practical sessions included new practical programming activities. These activities consisted of learning of two basic concepts: multiple inheritance and exceptions in an autonomous way.

In theoretical classes, students learnt that Java does not allow multiple inheritances, but can be achieved using interfaces. In order to illustrate how to do multiple inheritance in Java, teachers gave a research paper to students. In Spain, it is not usual that the teachers of the degree subjects give research papers to their students. The paper was titled "*Eliminando la herencia múltiple y el diamante de la muerte*" ("*Removing the multiple inheritance and the Death Diamond*"), by Diego Bravo Estrada [17]. It includes interesting reflections about some topics the students were learning. Besides, the paper contains many examples, so they could understand and even compile what the text explains. In fact, the exercise consists of solving the problems proposed in the article. These exercises illustrate a classical problem in multiple inheritance, that is related to topics such as simple inheritance and polymorphism. In the problem, there is a building with some properties and some methods associated. Furthermore, there are a hotel and a restaurant, which extend the building. And finally (what represents the key for the multiple inheritance), the paper proposes the idea of adding a hotel-restaurant to the model, which extends the hotel and also extends the restaurant. The students worked with inheritance and polymorphism. They also thought over the inheritance (simple and multiple), its problems and some possible ways to solve them. Of course, the solution is presented in the own paper, so they could consult if they would want, after having tried to do it. This practice respects their individual rhythm of learning. Furthermore, some questions related with the comprehension of the paper were asked to students. Mixing all, this activity is a full exercise, which works the knowledge, the comprehension and even the application level, talking in Bloom's taxonomy terms [16].

The second new practical session consist of teach the concept "Exceptions in Java" in a really practical way. Firstly, a very brief theoretical explanation was given to students. This explanation consisted basically of linking this concept with the "mistake" concept, and explaining (very briefly) the role that the exceptions play in the hierarchical structure of classes in Java. Then, a simple code related to exceptions was given in order to compile and run it. With this code, they understood why there are different types of exceptions. The code is gradually getting hardest, and new situations related to exceptions appear. At the end, they had seen the most typical scenarios they would find in many programs. This exercise, such as the previous one, is a guided exercise that assumes the students can see the solution when they would believe that it is time to do it. This type of exercises guides to students on their own learning, if they act with responsibility.

III. Results of the case study

Next, different results of the case study are presented including: i) the final scores obtained by the students of this subject compared to previous academic years, ii) results of the students related to the different learning activities proposed, and iii) data about the participation in the learning activities. The comments of the student experiences with the new active learning activities are included too.

Students of OOP subject at Universidad Rey Juan Carlos have two opportunities to pass the subject in the same year: June and September. During 2008-2009 academic year, there were 26 students in OOP subject. This year, the final score took into account all the activities performed by students and a final exam. Practical sessions, including the new ones, had a weight of 30%; the OO design exercises with PACS and the collaborative work with an oral public presentation were the 10% of the score and finally, the exam was the 60% of the total score.

Table I and II show the scores obtained by students of this subject along three different academic years, between 2006-2007 and 2008-2009 years in both two opportunities: June and September.

Table I presents the scores obtained in June opportunity. The total number of students who chose this subject is stable along these three academic years: 26 students for 2006-2007 and 2008-2009 years, and 25 students during the 2007-2008 year (see the last row in table 1). As it can be shown, the number of students who decide not to present to the final exam (NP row) decreases in the last year opposite to the previous years (only 9 students did not take the final exam against 15 students in other previous years). Furthermore, there are not any students who failed the final exam of June in the last year. These facts cause that the number of students who passed the final exam increased and, the better results rose too in the last year (see the increment of the ">=7 and <9" and ">=9" rows).

TABLE I. SCORES FOR DIFFERENT ACADEMIC YEARS - JUNE

	2006-2007	2007-2008	2008-2009
<5	4	3	0
>=5 and <7	3	5	11
>=7 and <9	2	2	5
>=9	0	0	1
NP	15	15	9
TOTAL	26	25	26

The improvement of the student scores during the last year can be observed in figure 4. The line with rhombus (blue colour) represents the number of students who failed the final exam. The line with squares (pink colour) represents the students who passed the final exam with the minimum knowledge required. The line with triangles (red colour) and the line with crosses (green colour) show the good and excellent student scores respectively at the bottom of the figure 4. Finally, the line with asterisks (purple colour) placed to the top of the figure, shows the number of students who decided not to present to the final exam. This last fact is really important because it means that students had been more motivated this year, and maybe the mix of the new learning activities with the previous ones would have contributed to it.

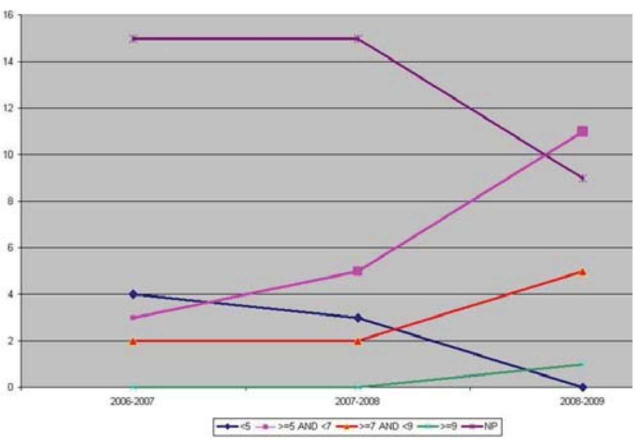

Figure 4. Scores for OOP subject during three years

Table II presents the scores obtained by students during these three academic years in the September opportunity. The number of students who had to present to the final exam in this opportunity were 21 students in the 2006-2007 year, 18 students in the 2007-2008 year and finally, 9 students in the last year. It is important to remark that the last row of this table does not includes the number of students who passed the subject in June opportunity.

TABLE II. SCORES FOR DIFFERENT ACADEMIC YEARS - SEPTEMBER

	2006-2007	2007-2008	2008-2009
<5	1	2	1
>=5 and <7	3	6	1
>=7 and <9	2	0	1
>=9	0	0	1
NP	13	10	5
TOTAL	21	18	9

The total number of students who did not pass OOP subject was 14 in 2006-2007 year, 12 in 2007-2008 year and, 6 in 2008-2009 year (obtained of "<5" and "NP" rows of Table II). We observed that this method achieves a significant decrement of these students. Only the 23% of total students did not pass subject in 2008-2009 year regarding to 54% in 2006-2007 year and 48% in 2007-2008 year. These global results show a clear improvement in the scores of the students and a fall in the number of students who drop out the OOP subject during the last course.

Regarding the results of the OO design exercises and the '*Programming Assignment Correction System*', there were 21 students who participated in this activity against 5 people who did not it. The participation of the students in this subject was high. Figure 5 shows the scores obtained in this new active learning activity by the students.

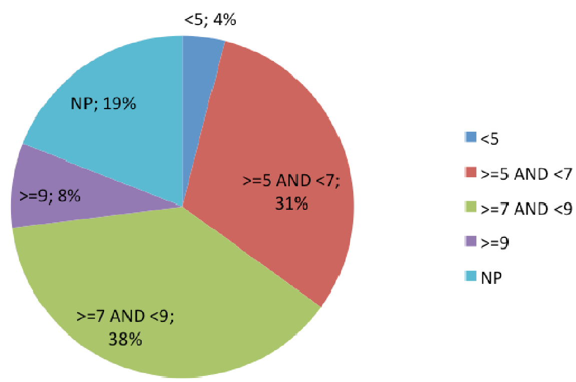

Figure 5. Scores of the students in the OO design exercise

In general, all the students did their exercises and corrected the classmates' exercises appropriately, taking into account the criteria given by the teachers of the subject. Only one person did not take seriously the peer review process of the solution of his partners, and he fails this activity because this is a requirement to obtain the maximum score. Furthermore, students performed better corrections to their partners than their own solutions.

After doing this activity, an opinion poll was done to the students in order to capture the feelings of the students about this type of active learning activity. The peer review process with PACS was easy for the students. They did not need to spend too much time reviewing the exercises of their partners.

This is owing to the fact they have already worked in OO design exercises previously. This type of activity is funnier than other classical learning activities because they can interact with their classmates and helping between them. They like seeing the correction process adopting the teacher role and teaching one another. They understand the comments of their partners in an easy way and they accepted better the critics and comments of their partners. The comments of their partners motivate them and they are a good feedback before obtaining the comments of the teacher.

Students who used Internet Explorer Web browser had some difficulties with PACS when they tried to upload their comments and corrections to the system because this system is optimized for Mozilla Firefox.

Regarding the collaborative work and the oral public presentation, the results were excellent as it can be seen in figure 6. Only three students had not presented this work to the rest of the classroom. Students made presentations whose quality was good or excellent. They explained to their partners the main characteristics of the topic selected and they established the relationships with the concepts explained during previous theoretical classes of the course. Furthermore, they were able to answer the questions performed by their own partners and the teachers. This activity motivates students because they knew new concepts that allow having a global view of more useful topics related with the concepts explained in the course.

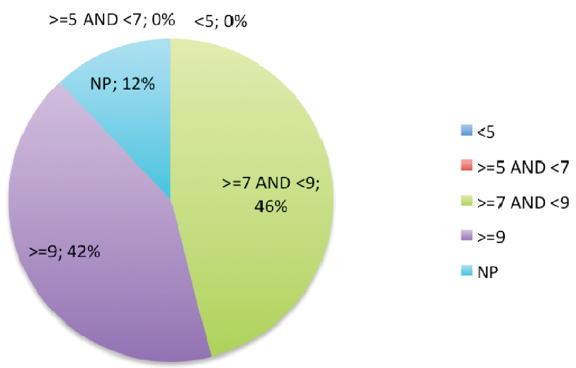

Figure 6. Scores of the students in the collaborative work and presentation

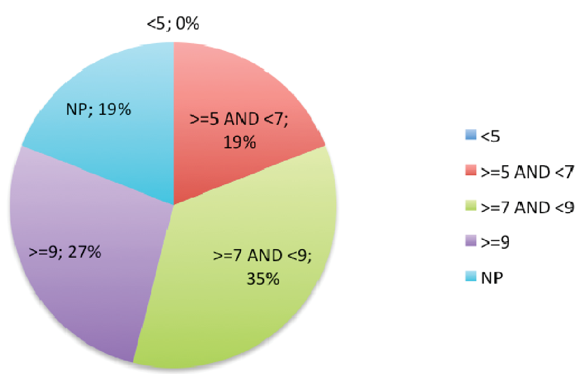

Figure 7. Scores of the students in practical sessions

Finally, the scores obtained by students in the practical sessions are presented in figure 7. As it can be seen, there is nobody who failed the practical sessions. However, there are five students who did not present their practice exercises. In general, scores are really good since 16 students (equals to 62% of the total) obtained a score higher than 7.

IV. CONCLUSIONS

This paper has presented a case study of the experience to include new active learning activities in the Object Oriented Programming (OOP) subject of Telecommunication Engineering at Rey Juan Carlos University. As it can be seen in the results presented of the previous section, the number of the students who drop out the subject decreased against previous year. This is a good indicator to continue applying this methodology. Also, students get higher scores than last years. These two facts are really important. We think that the mix of different active learning activities (theoretical classes, practical sessions, the use of PACS, and the collaborative work with the public presentation) improves that students are involved in their own learning process and they are more responsible on their study. For this reason, their motivation for the subject increased.

Furthermore, the new learning activities included the last academic year aroused interest for this subject. Many students of Telecommunication Engineering choose this subject and then they drop out because it is not enough related with their career. This year, we have achieved that students understand the usefulness of OOP in Telecommunication area and they are able to applied technologies connected with the concepts of this subject.

The peer review process using PACS allows to students receive feedback from other classmates immediately. They learn from the solutions of their partners. This system supports the interaction between students allowing becoming aware of their own mistakes or learning misconceptions, understanding multiple choices to solve the same problem, taking ideas to improve their own solutions or to do other similar exercises, and so on. This type of activity has allowed that students acquired deep knowledge of object oriented design. Furthermore, students put in practice the development of some personal and social skills such as critical thinking and communication abilities. Regarding the work load in accomplishing these activities, students did not spend too much time in the review process. Students are a really hard teacher with their corrections; they correct the exercises of their partners conscientiously, detecting small mistakes and explaining each error and the possible solutions.

The collaborative work performed in workgroups about a selected topic with a public oral presentation promotes the active and autonomous learning and the development of communication skills. The random selection of the person who is the responsible to present the work to their classmates guaranteed that each member of the groups worked in the collaborative work and he understood the topic selected. Students performed good and excellent presentations. They had to understand and analysis the possible uses of the topic. When students had to choose a topic of the list proposed, the most selected topic was "Java and mobile devices" because it is the most related topic with Telecommunication Engineering.

Therefore, although the new active learning activities have a small weight in the final score of this subject, we think that these activities have contributed to motivate to the students in their own learning process. Students like new teaching methods where they are the centre of their own learning and the activities proposed are more dynamic.

Mixing different types of activities, students understand better the concepts explained during the whole course because they are working the knowledge, the comprehension and even the application level, talking in Bloom's taxonomy terms. For this reason, their acquired knowledge remains during a long time. This mix promotes the lifelong learning.

ACKNOWLEDGMENT

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Reviews and Findings on Implementing Active Learning in a Large Class Environment

for Mechatronics and Computer Science students

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***Abstract*— This paper tackled the issues of different learning preferences for Computer Science and Mechatronics students in a large class environment by using different active learning methodologies. Apart from implementing active learning methods in the class, another idea present here is coupling with another course. The efforts required and the effectiveness for these methods are being presented, with this the suitable methods can be selected depending on the participants and the resources available.**

***Keywords*—Computer Science education, Education, Engineering education, Mechatronics**

I. INTRODUCTION

The class size in the universities starts to grow when higher education ceases to be “only for the elites” but also “for the masses” [1]. The most common pedagogy form for large class setting is the lecture setting. A traditional lecture takes place when a lecturer recites or pass on the knowledge in verbal form while the students take note [2]. Among the challenges in a large class settings are it is more difficult to control the class behavior [3], to follow up on students’ understanding, and to encourage students’ participation in the class. In order to overcome these problems, different methods under the term “Active Learning” were introduced. Active learning means the students not only listen and take notes in the class but they also have the opportunity to participate actively in the class [4]. Among the methods implemented in active learning include informal group learning, formal group learning, problem based learning, group work, team-teaching, cold calling, in-class demonstration, muddiest card, flash card, concept test, evaluation form, pause method, laboratory work, and learn management system [2,5,6,7,8]. The different methods mentioned above can be divided into two categories, those that can be implemented in the class and those to be implemented outside the class (see Table I).

Implementation of active learning methodologies requires more effort and resources. As described by Bonwell and Sutherland [5], among the challenges include the decrease of total covered contents, the increase of preparation effort, and the lack of materials and resources. Active learning can be implemented in both large and small class. The size definition used in this paper is as described by Kuo [9]. A small class has less than 25 students, whereas a large class has more than 75 students.

This paper focuses on the introduction of different active learning methods implemented in the course for Mechatronics and Computer Science students in a large class environment with limited resources. Section 2 introduces the course content, the settings of the course and the challenges faced. Section 3 to 5 present the methods implemented in the class outside the class but within the frame of the course, and outside the class through coupling with another course. Section 6 to 8 discuss on the findings for the different methods implemented. The last section concludes this paper by comparing the different methods to its impacts and effort needed for implementation.

TABLE I. IN CLASS AND OUT OF CLASS ACTIVE LEARNING METHODS

Methods	In Class Implementation	Out of Class Implementation
Informal / Formal group learning	X	
Problem based learning	X	X
Group work	X	X
Team-Teaching	X	
Cold Calling	X	
In Class Demonstration	X	
Muddiest card	X	
Flash card	X	
Concept test	X	
Evaluation form	X	
Pause method	X	
Laboratory work		X
Learn management system / Internet		X

II. COURSE INTRODUCTION

A. Course Content

The course Embedded System 1 with course code FB16-6951 (ES1) and Embedded System 2 with course code FB16-6952 (ES2) were introduced at the Faculty of Computer Science and Engineering, University Kassel [26] in summer

TABLE II. COMPARISON OF RESEARCH WITH DISCIPLINES, CLASS SIZE AND METHODS IMPLEMENTED

Item	Source	Disciplines	Disciplines	Contributing Dept.	# of Students	Lab work	Remote Lab/ LMS	Traditional Lecture	Group work	Project with External	Active Lecture	Tutorial	Muddiest card	Flash Card
1	[10] (Murata & Stern, 1993)	Mechatronics	1	1	M	X	X	-	-	-	-	-	-	-
2	[11] (Cowan, Ewell, & McConnell, 1995)	Religion, English	2	2	M	X	-	X	-	-	-	-	-	-
3	[2] (Mills-Jones, 1999)	Computer Science, Business	2	3	L	-	-	X	X	X	X	S	-	-
4	[12] (MacGregor, 2000)	English, Philosophy, Sociology	2	3	L	-	-	-	X	-	-	-	-	-
5	[12] (MacGregor, 2000)	English, US History	2	2	L	-	-	-	X	-	-	-	-	-
6	[13] (Grimheden & Mats Hanson, 2001)	Mechatronics	1	1	-	X	-	-	-	-	-	-	-	-
7	[14] (Wikander et al., 2001)	Mechatronics	1	1	-	-	-	-	X	-	-	-	-	-
8	[15] (Tomizuka, 2002)	Mechatronics	1	1	-	X	-	-	-	-	-	-	-	-
9	[5] (Hall, Waitz, Brodeur, Soderholm, & Nasr, 2002)	Engineering	1	1	M	-	-	-	-	-	X	S	X	X
10	[16] (Cooper, Carlisle, Gibbs, & Watkins, 2002)	Medical	1	3	-	-	-	-	X	X	X	S	-	-
11	[17] (Sargison, Bullen & McCulloch, 2002)	Engineering	4	4	L	-	-	-	X	-	-	-	-	-
12	[18] (Shooter & McNeill, 2002)	Mechatronics	1	2	-	X	-	-	X	-	X	-	-	-
13	[19] (Erbe & Burns, 2003)	Mechatronics	1	2	-	X	X	-	-	-	-	-	-	-
14	[20] (Amey & Brown, 2005)	Sociology	5	5	-	-	-	-	-	X	-	-	-	-
15	[7] (Smith, Sheppard & Johnson, 2005)	General	-	-	S	-	-	-	X	-	-	-	-	-
16	[21] (Graber & Pionke, 2006)	Engineering	1	2	M	-	-	-	X	-	X	-	-	-
17	[22] (James, 2007)	General	-	-	M	-	X	-	X	-	-	X	-	-
18	[23] (Pears & Daniels, 2007)	Engineering	1	1	S	-	-	-		-	-	-	-	-
19	[24] (Sommers & Engbretson, 2007)	Engineering	1	1	S	-	-	-	X	-	-	-	-	-
20	[25] (Mitusi, Kambe, Satoshi Endo & Koizumi, 2008)	Engineering	1	1	S	X	-	-	X	-	-	-	-	-
21	University of Kassel	Mechatronics, Computer Science	2	1	L	X	-	X	X	-	X	M	X	-
	Total for Implemented Methods					8	3	3	13	3	6	5	2	1

Legend: S- Small; M- Medium; L- Large; X-.Implemented

semester 2006 and winter semester 2006/07 respectively. These courses are compulsory for Mechatronics students and Computer Science students who are in their third and fourth semesters. The objective of this course is to train the students to think independently and be able to work in team when developing an embedded system.An embedded system is an embedded hardware/software system that regulates a physical device by sending control signals to actuators in reaction to input signals provided by its users and by sensors capturing the relevant state parameters of the system [27]. The ES1 subjects focus on the development of microprocessors. Among the subjects covered in ES1 are Logic and Gates, Computer Architecture, Scheduling, Programming Languages – PEARL, Assembly Language and VHDL, and Bus System. The ES2 subjects focuses on the development lifecycle of an embedded system [28]. The subjects in this course include Requirements Engineering, Modeling Methods, Automation Technology (with focus on hardware and architecture), Programming Language – IEC 61131-3, and Verification, Validation and Test.

Both these courses are courses with two semester hours a week. One semester hour is 45 minutes. The lecture and the exercise sessions take turn in almost alternate weeks. All sessions last for 90 minutes. There are no prepared lecture notes but the students are able to download the presentation slides from the professor a week before the respective lecture. The week before the exercise session, the exercise questions are uploaded to the internet. This enables the students to work on the questions prior to the exercise sessions.

B. Course Challenges

The first challenge is the discipline diversity of the participants in the courses. Averagely, 66% of the course participants are Computer Science students and another 34% are Mechatronics students. The participants from Electrical Engineering students are negligeble. They are less than 1 % if any. These students have different cognitive minds and response to the different methods differently. The students understand the term modelling differently. During a question answer in the class, the Mechatronic students relate modelling to the modelling of a physical system, where as the Computer Science students relate it to the design of a software system. According to Grimhenden and Hanson [13], Mechatronics students prefer practical work. As shown in Table II, the most implemented active learning method for Mechtronics students are group work, where the students develop a physical system. They are conducted in groups of two or three.

Secondly, the class size for both the courses are large. The average participants for ES1 is 100 students, whereas ES2 is 80 students. The implementation of active learning in a large class environment will be more challenging. Arias and Walker [29] argued that the small class students tend to fare better than those from large classes do. The research undertaken to implement active learning in large class environment [2,5,21,25] showed that much resources are required. This leads to the third challenge, the limited human resources.

The third challenge is the limited human resources. Interdisciplinary courses are courses where more than one disciplines are taken into considerations [30]. The course discussed in this paper is considered as interdisciplinary course [31]. From the research conducted (see Table II) the number of the contributing departments for interdisciplinary course is usually more than the number of disciplines. This also means that at least a professor and teaching staff from each department are available to conduct the course. As shown in item 21 in Table II, the course consisted of students from two different disciplines – the Mechatronics students and the Computer Science students. However, unlike most of the research done, where the number of contributing departments is more or same as the disciplines involved, here, the opposite happens. The number of disciplines is two, whereas the contributing department is only one. A professor and a teaching assistant are responsible for this course. The ratio between teaching resources to students is 1 to 80.

The three challenges faced in this course will be discuss overall. Different methods implemented in the course of 5 semesters to cater to the diversity of the class, to overcome the barriers of large class environment and to make full use of the limited resources available will be presented. The implemented methods will be addressed in three categories, namely the methods implemented

- in the class,
- partially outside the class but within the frame of the course, and
- outside the class as coupled with another course.

III. METHODS – IN THE CLASS

A. Methods implemented during the Lecture

In order to maintain the students' attention, the lecturer very often includes students' participations in the lecture. Among the methods used in the lecture are

- in class demonstration with participations from students,
- asking questions to the students without embarrassing them, and
- presenting the idea visually on the board even though the class also uses slides presentation.

An example of an in class demonstration with students' participation is the join process in a Petri Net. In order to explain the tokens, places and transitions, four students participate in this demonstration. One student will hold the pen cover, and the other the pen. Both these students are the places with the pen and the cover as the tokens. Next, the pen and the cover will be passed to a student who plays the "transition" role. The student will put the pen and the cover together, and then passed the covered pen as a single token to the next student. Different role plays were conducted to explain the different process that can take place in a Petri Net.

As to asking questions in the class, the round robin method was implemented. If the student is not able to answer the question, the person next to this student will be next in row to help him/her out. Not much time is spent waiting to avoid embarrassment. This method not only keeps the students involved but also awake, as the class starts at 8:15 in the morning.

Even though the information is available in the handouts for the students, it helps to draw the students' attention when this information is once more presented on the board. For example drawing a microprocessor part by part, and explain the functions of each component as they are drawn on the board.

B. *Methods implemented during the Exercise*

During the exercise session, which takes place almost alternate weeks, students are requested to work out the exercise problems on the board. However, the response had not always been positive. A few minutes will be given for the students to discuss the problem with their neighbor if most of the students did not work out the questions before hand. They would then be requested to solve the problem on the black board in front of the class.

In order to encourage the class participations, the teaching assistant tried to remember as many names as possible and to call these names in the class. However, the number of names remembered is at most 15. It was also not exactly "fair" to repeat the few same names weeks after weeks. The second method used to encourage students participation was to have a name list and to pick a name from this list. However, some students will pretend as if they were absent, choose to remain silent and not proceed to work out the problem even though they are actually in the class. In summer semester 2009, the teaching assistant tried a new approach. The tool was a packet of facial tissue paper. The teaching assistant posed a question and threw the packet to the first student who was supposed to answer the question. The student then in turn can throw the packet of tissue to another student for the next question. This method had been the most welcomed method as compared to the first two. This also brought some fun factors into the class.

C. *Bench Scale Equipment as Example*

Throughout the lecture of ES2, bench scale equipment was introduced. The purpose is to use a consistent example during the lecture and exercise, with the idea that this would help the students' understanding on the course content. The bench scale equipment is a stamping and sorting machine. The equipment can be divided to four modules, namely the storage module, the

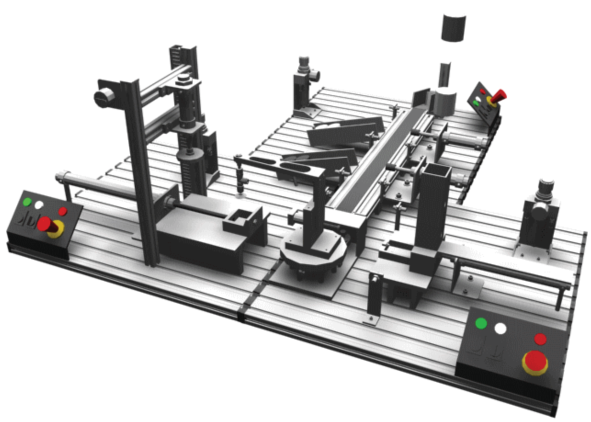

Figure 1. Bench scale equipment with four modules

crane module, the stamping module, and the sorting module. The students were taught how the sensors and the actuators function. The storage module is the simplest module where a tactile sensor will sense if there is a work-piece that needs to be pushed out. The crane will pick the work-piece and send it to the stamping module and than later to the sorting module. Examples for requirements engineering, system modeling, program development, and testing was based on this equipment when possible.

D. *Pop Quizzes*

Pop quizzes are impromptu quiz conducted at the beginning of the class. The purpose of pop quizzes is to encourage students' attendance and to have an in between overview on how much did the students understood in the previous lectures. Two or three pop quizzes will be conducted through out the semesters. Fifteen minutes were given to the students to finish up the quizzes. The motivation for participating in the pop quizzes is the possibility to include pop quizzes' results in the final result of the course. The students who participated in pop quizzes can at most increase their marks by 15%.

IV. Methods – Partially Outside the Class

A. *Group Work with Partial Life Cycle Development*

As the content of ES2 focuses on the development of an Embedded System, the idea is to allow the students to go through the different life cycle phases using group work. In summer semester 2007, the students were divided into groups of 10. Each group was responsible for a chapter covered in the course. As observed in Fig. 2, the students were divided into nine groups. In order to encourage communications from the different disciplines, it was a pre-requisite that the group should be 70% Computer science students and 30% Mechatronics students.

No specific tool was implemented here. The students can

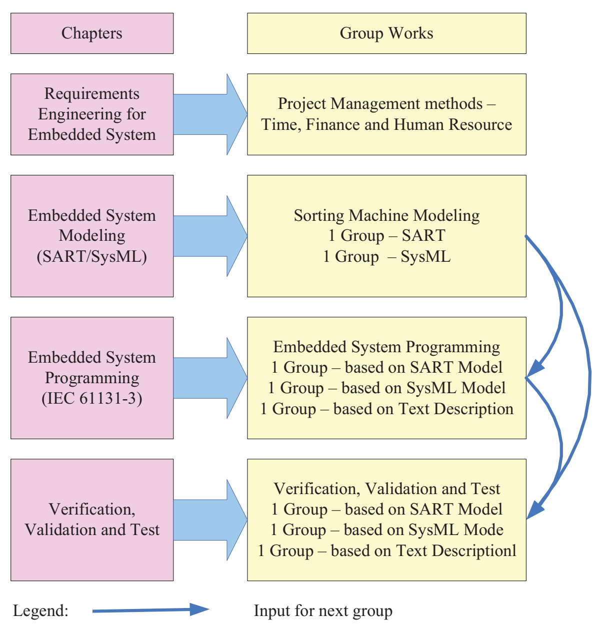

Figure 2. Bench scale equipment with four modules

select tools that they know or ordinary drawing tools to model the system in "Structured Analysis with Real Time Extension" (SART) [32] or "System Modeling Language" (SysML) [33]. The programming was conducted in the exercise session by writing the program either in structured text or in function block. The main objective here is to observe what the students can understand from the modeling diagram. The validation and test group will then compare if the functions mentioned in the modeling diagram were fulfilled in the program.

Each group was expected to deliver a written report and a 15 minutes presentation. Each group had a fix appointment with the teaching assistant two weeks before the presentation session. This ensured that the students are on the right track and well-prepared for the presentation. They can make extra appointments when necessary. The presentation was conducted during the exercise session. Therefore, during summer semester 2007, thirty minutes from the one and a half hour exercise was used for group works' presentation.

B. *Group Work with Whole Life Cycle Development*

In summer semester 2009, a different concept of group work was implemented. The students were again divided into groups of tens. This time instead of making it a pre-requisite, the students were encouraged to have a group with members from both disciplines. However, the Computer Science students grouped automatically with the Computer Science and the Mechatronics with the Mechatronics. This shows that students are still more comfortable to work with the people they are familiar. In order to encourage interdisciplinary communication and group work, the group distribution with students from different disciplines needs to be intentional.

TABLE I DIFFERENT ASSIGNMENTS IN GROUP WORK

Project Assignment	Description
Part A: Requirements Engineering	1) Decide on the job description of each member 2) Requirement document for the system
Part B: System Modeling (SART)	1) System modeling document
Part C: System Modeling (SysML)	1) Report on modules that can be reuse
Part D: System Development (Own Group)	1) System simulation 2) Report on document evaluation from part A to C.
Part E: System Development (Another Group)	1) System simulation 2) Report on document evaluation from part A to C.
Part F: Test and Validation	1) Test cases and test result for own system
Part G: Group Work Evaluation	1) Evaluation report

The same bench scale equipment was used as the foundation for the group work. Instead of working on one of the lifecycle phases, the same group had to start from requirements gathering and ends at verification, validation and test. Using the different actuators and sensors introduced in the class, the students were requested to design a system on their own. They needed to produce a requirement document, explaining the system description. Next, they would need to design the system using SART, and observe on any possible reusable modules and present it using block definition diagram and internal block diagrams from SysML. After that, they would develop a simulation for the system using TrySim [34]. Apart from developing their own system, the group received a copy of system description and system modeling from another group, and they should implement the system from another group as well. Table III describes the different assignments in this group work.

For assignment parts A to C, the students were free to use any drawing tools that they are familiar. However, the students were also encouraged to attend an additional related course, which will be described in the following chapter, to learn the tools that they can use for the whole lifecycle process. The simulation software needed for part D and E was presented during the exercise and was also taught in this coupled course. Unlike the former group work, no in-class presentation was arranged. The students only need to do one presentation at the end of the group work

V. METHOD – COUPLING WITH ANOTHER COURSE

A. *Loosely coupled Software Tools*

In summer semester 2007, the course Software Tools with course code FB16-6959 (SWT) was introduced. This was a two semester hours week course, meaning the students needed to attend a 90 minutes class/lab session each week. The objective of this course is to introduce different software tools that can assist the engineering process. These different software tools can be mapped into the different development life cycle of an embedded system. Therefore, the coupling is done by first teaching the theory in ES2 lecture and then practical in SWT. In summer semester 2007, the tools introduced in SWT were IBM RequisitePro Software [35] for Requirements Engineering, Visual Object Net++ [36] for Petri net, Enterprise Architect [37] for UML [33], and TrySim [34] for IEC 61131-3 programming. The students worked in pairs to solve the problem using the different tools.

Before the semester began, the schedule for SWT and ES2 were coordinated in such a way that the practical work in SWT should only be conducted after the subjects were taught in ES2. SWT also used the same bench scale equipment as case study for the class. However, the functions of the equipment were modified. The students were requested to sort the work-pieces differently as those in ES2. The students were graded base on the practical work delivered throughout the whole course. There is no written test for SWT.

B. *Closely coupled Software Tools*

Through the SWT course evaluation from summer semester 2007, we learnt a few lessons. The course arrangement scheduled during the beginning of the course was not optimal as there were times when ES2 lectures took longer than expected to finish or the subjects were rescheduled due to unforeseen circumstances. ES2 taught the students SysML but in SWT, UML was implemented. As a result, a number of students were confused as both mark-up languages share a number of similar points though they are different. The students who participated in both ES2 and SWT claimed that the same lab bench equipment with different software functions confused them.

For summer semester 2008, a few different methods were implemented. Firstly, the first three weeks of SWT were used for two lectures on lifecycle process and the selection of tools, as well as group organisation. This gave SWT a three weeks' buffer if ES2 schedule is delayed due to unforeseen circumstances. Secondly, instead of teaching UML, the students were taught SysML. This would avoid any confusion that might occur. SysML was chosen as SysML includes modelling of system architecture and behaviour.. Thirdly, throughout the whole ES2 and SWT classes, the students were reminded that the same hardware can have different software functions. The same lab bench equipment was used for ES2 and SWT but their software functions are different.

The tool IBM Requisite Pro Software excluded from the course Software Tools for summer semester 2008. This is due to two reasons. Firstly, from past experience, the students needed at least three weeks (three practical sessions) to be familiarized with the tool. Secondly, we received six sets of network kit where the students can configure the connections between computer and controller and test download the programs for the controllers. The network controller kit was coupled with the Bus System chapter that was brought forward from ES1.

VI. BASICS FOR ANALYSIS

A. *Data Source*

There are three batches of students involved in this study. As shown in Table IVA, they are batch 0607, 0708, and 0809. They each stands for the semesters where ES1 takes place. Batch 0607 includes ES1 in winter semester 2006/07 (ES1 WS0607) and ES2 in summer semester 2007 (ES2 SS2007). The same applies to batch 0708 and 0809.

TABLE IIA METHODS IMPLEMENTED IN THE DIFFERENT SEMESTERS

Batch	0607		0708		0809	
Implemented Methods	WS0607	SS2007	WS0708	SS2008	WS0809	SS2009
Pop Quiz	--	--	X	X	X	--
Group Work	--	X	--	--	--	X
Software Tools	--	X	--	X	--	X

TABLE IVB DATA SOURCE FOR ANALYSIS

Data Source	WS0607	SS2007	WS0708	SS2008	WS0809	SS2009
Course Exam Result	X	X	X	X	X	X
School Exam Result	X	X	X	X	--	--
Course Evaluation	--	X	--	X	X	X
Group work Evaluation	--	--	--	--	--	X

Three main data source were used to analyze the effectiveness of the different methods (see Table IVB). They are the course evaluation conducted at the end of the semesters, the group work evaluation for summer semester 2008, the group work, pop quizzes and exam results from the students. The data were collected across five semesters, from summer semester 2007 to summer semester 2009.

When comparing the effectiveness of different methods in a particular semester, no extra point grade will be used. The students who participated in the pop quizzes or group work had the opportunity to collect extra 15% points. A student who did not participate in pop quizzes nor group work can have 100% full score but a student who did can have 115% for full score. For example, a student earned 10% extra point from the pop quizzes or group work and in the final exam this student scored 70%. The no extra point (NEP) percentage is 70%, whereas the extra point percentage (WEP) is 80% (10% + 70%). "No extra point grades" are the grades according to the NEP percentage and "extra point grades" are the grades according to the WEP percentage.

In order to have fair comparison, the exam results for other courses from the same batch of students for that particular semester were taken into consideration. This will function as the control data for comparison with ES1 and ES2. Even though it is not compulsory for the students to follow the semester plan, from the course evaluation, we discovered that almost 57% of the Computer Science students and 97% of the Mechatronics students do follow the semesters plan. Therefore, it is reasonable to use the overall grade from the semester as control data. The ES1 and ES2 grades used here are the final grades that include the extra points accumulated through pop quizzes or group work. As the control data for batch 0809 is still in process, only control data for batch 0607 and 0708 are available.

The grading used in Germany is from scale 1 to 5, with 1 as the best grade and 5 as the poorest grade. The grades used for comparison are the average grades, unless mentioned otherwise. In the following, control grade means the average grade for control data and course grade means the average for course grade. 2-tail tests at $\alpha = 0.05$ are mainly used in the analysis, unless mentioned otherwise. The students' results from the different semesters fulfills the normal distribution.

B. *Comparison with Control Data*

TABLE III COMPARISON OF STUDENTS IN ES1 AND ES2 TO CONTROL DATA

Computer Science	Control Data			Course Data		
	N	Average	Std. Dev.	N	Average	Std. Dev.
WS0607	298	3,436	1,2232	71	3,515	1,3920
SS2007	139	2,900	1,0476	50	2,884	1,0223
WS0708	258	3,322	1,2917	52	3,404	1,0066
SS2008	147	3,354	1,1637	45	2,984	1,4327
WS0809	--	--	--	50	2,946	1,3577
SS2009	--	--	--	56	2,850	1,2262

Mecha-tronics	Control Data			Course Data		
	N	Average	Std. Dev.	N	Average	Std. Dev.
WS0607	78	3,082	1,132	25	3,932	1,3247
SS2007	91	2,924	1,1261	24	3,054	0,9302
WS0708	140	2,800	1,1000	33	3,036	1,3583
SS2008	149	2,951	1,0771	27	2,419	1,4531
WS0809	--	--	--	29	3,007	1,5597
SS2009	--	--	--	24	1,662	0,7523

Computer Science

The average grade for the course and control grade improved significantly for batch 0607. The average grade for ES1 WS0708 was 3.404 and it improved significantly (with p = 0.10) in ES2 SS 2007, with 2.984 (see Table V). There was no significant improvement for the control grade for batch 0708.

The course grade for ES2 SS2008 is significantly better than control grade. Similarly, to batch 0708, there is also no significant improvement for the course grade in batch 0809. Therefore, the following two conclusions can be made for Computer Science students:

- The students performed better in ES2 as compared to ES1 for batch 0607, 0708, and 0809
- The methods implemented in ES2 SS2008 have more positive impacts than the methods implemented in ES2 SS2007 and ES2 SS2009.

Mechatronics

There is no significant improvement between the semesters for the control data. The average grade for the control data was 3.082 for winter semester 2006/07, 2.924 for summer semester 2007, 2.800 for winter semester 2007/08, and 2.951 for summer semester 2008. Unlike batch 0607, the control data's average grade for summer semester 2008 was poorer than the winter semester 2007/08. As for ES1 and ES2 average grade, the average grade for batch 0708 shows no significant difference but the grade for batch 0607 and 0809 shows significant improvement. The average grades for batch 0607, 0708 and 0809 are as follow: 3.932 and 3.054; 3.036 and 2.419; and 3.007 and 1.662. The following two conclusions can be made for Mechatronics students:

- Just like the Computer Science students, the Mechatronics performed better in ES2 as compared to ES1 for batch 0607, 0708, and 0809
- Unlike the Computer Science students, the methods implemented in ES2 SS2008 were least significant for the Mechatronics students.

VII. Analysis – Methods in the Class

A. *Methods in the Lecture and Exercise*

The observation for the methods implemented in the lecture and exercise are done through the feedbacks in the course evaluation form and the students' participation in the class. We conclude that the question and answer, demonstration in the class and students having the opportunity to work out the problem in the class have positive impact.

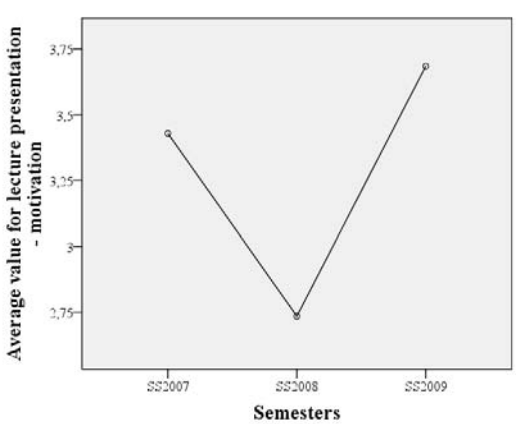

Figure 3. Average value for motivation in the lecture

The communication with the students in the class has more influences than the slides, in attracting students' attention and interest to the contents of the courses. The students who participated in ES1 and ES2 commented that there were too many slides. As comparison, other courses in the faculty provide lecture notes and as a result have simpler lecture slides. As there were no prepared lecture notes for ES1 and ES2, the slides had the function to provide the additional related information that the students need. Efforts to reorganize the slides took place in ES2 SS2008 but the students still find the slides and the course content overwhelming. In ES2 SS2009, another lecturer uses the same slide for lecture. However, unlike the previous lecturer, this lecturer had almost no communication with the students. Students were not questioned in the class, short pauses were made to ask if they have any question but the class remains silent most of the time. Using the evaluation feedback for ES2 SS2007, ES2 SS2008 and ES2 SS2009, there was a significant difference for the motivation in lecture for the different students. The motivation for SS2008 was the best, followed by SS2007 and SS2009 (see figure 3). Even though the understanding on the course lecture also follows the same pattern but the average did not differ significantly when using one-way ANOVA test. The attendance for ES2 SS2009 also dropped drastically when compared to other semesters. There were time when only 20 out of 80 students attended lecture.

B. *Implementation of Bench Scale Equipment*

The same bench scale equipment was implemented for both ES2 and SWT. This saved time in explaining how the different hardware functions and the slides prepared can also be used for both courses. There were few comments in the evaluation form saying that the bench lab equipment should be introduced earlier. In the group work evaluation for ES2 SS2009, 65.9% of the students graded the bench lab equipment as useful or very useful in helping them to understand the course content. Another 20.9% was neutral and only 13.2% graded it as not useful and not useful at all.

From the teaching assistant point of view, using the same bench lab equipment saved preparation time in terms of preparation of lecture slides, exercise slides, and helped students to understand what can be implemented in the group work. This gave the students the time to gain needed understanding on the selected hardware structures and the respective software implementations. However, as the same hardware with different software might cause confusion to the students, it is important to stress this frequently in the class. No students complained about this issue in the latest evaluation.

C. *Implementation of Pop Quizzes*

Generally, students who participated in pop quizzes fared better than those who did not. Except for winter semester 2007/08, the students who participated in pop quizzes scored significantly better. The expected advantage of the students' participation in the pop quizzes is to help students familiarize with the exam questions' pattern, besides having a more consistent revision on important course contents. Another possible advantage might be students who sat for pop quizzes are able to estimate time needed per question better.

TABLE IV COMPARISON OF PARTICIPANTS AND NON PARTICIPANTS FOR POP QUIZZES

Pop Quizzes			Participants			Non-Participant			Significance
			N	Average	Std. Dev.	N	Average	Std. Dev.	
Computer Science	ES1	WS0708	52	3,506	0,9662				
	ES2	SS 2008	25	2,692	1,1622	20	4,070	0,9251	0,000
	ES1	WS0809	29	3,069	1,3696	21	3,371	1,1829	0,419
Mecha-tronics	ES1	WS0708	30	3,100	1,1858	3	4,333	0,5774	0,088
	ES2	SS 2008	20	2,400	1,2703	7	3,857	0,8772	0,010
	ES1	WS0809	15	2,320	1,4047	14	4,114	0,9281	0,000

The average grade for students who took part in pop quizzes is significantly better in ES2 SS2008 but not in ES1 WS0708. The improvement of average grade for Computer Science students in batch 0708 who took part in pop quizzes is from 3.506 to 2.692, whereas the improvement for Mechatronics students is from 3.100 to 2.400 (see Table VI). This average grade improvement is not observed in batch 0809 where pop quiz is implemented in ES1 and group work in ES2. One reason might be that after two semesters of pop quizzes, the students can understand and answer the exam questions better.

There is a significant difference when comparing the attendance for group works that were implemented in ES2 SS2008 and ES2 SS2009, with the attendance for pop quizzes that were implemented in ES2 SS2008 and ES1 WS0809. The attendance when pop quizzes were conducted is better than the group work.

The implementation of pop quizzes seems to be the most effective methods in preparing the students to answer the exam questions. The extra effort needed to implement this are the time for the pop quizzes preparation, quiz marking, and the discussions with the students after each pop quiz. Averagely, 4 hours were needed to prepare a 20 minutes pop quiz, 30 minutes to correct the forty quizzes, 30 minutes to discuss the quiz questions and answers with the students, and another 30 minutes for extra organization works. Each pop quizzes is estimated be an additional 5 to 6 hours work for the teaching assistant.

VIII. ANALYSIS – METHODS PARTIALLY OUTSIDE THE CLASS AND COUPLING WITH OTHER COURSE

A. Comparison of Partial Life Cycle with Whole Life Cycle Development Group Work

Out of the 74 students in summer semester 2007, 57 took part in the partial life cycle development group work. There is a significant difference between the average grades. Students who participated in the group work scored 2.746 as average grade, whereas those did not scored 3.588. The average grade for those who participated in whole life cycle development group work in summer semester 2009 is also significantly better than those did not. The students who participated in the group work scored average grade 2.310 while those did not only scored 3.055. 51 from the 80 students participated in the group work in summer semester 2009.

Table VII separates the Computer Science students from the Mechatronics. It is interesting to note that the Computer Science students and the Mechatronics students have almost the opposite effects. The average grade for Computer Science students who participated in the partial group work was significantly better than those who did not, and the average grade for those who participated in the whole life cycle group project was significantly poorer than those who did not. The opposite is true for the Mechatronics students. One clear conclusion that can be drawn here is whole life cycle group work strongly influence the Mechatronics students, this supports the idea from Grimhenden and Hanson [13].

As compared to the partial group work in summer semester 2007, the Computer Science students' participance was lower in the whole life cycle group work in summer semester 2009. One reason given by the students who did not participate was the group work is too time-consuming. The partial life cycle group work requires the whole group work on one phase and the work can be completed in two to three meetings. The whole life cycle group work, on the other hand, will require more co-ordination effort and students might need to be involved in more than one phase of the life cycle. The Computer Science students commented that the extra 15% point is not worth the effort. They would prefer to use the time to revise on their own.

The effort needed to conduct partial life cycle group work was less than the whole life cycle group work. Only one to two appointments with the students were needed for the partial life cycle group work, where as the whole life cycle group work required at least four appointments, where each appointment had a duration of 30 minutes. The group work presentation for the partial life cycle group work was conducted in the class, where as extra appointment during the semester break was used for the group work presentation. Almost eight extra hours were required to conduct partial life cycle group work but at the expense of thirty minutes of the exercise. The whole life cycle group work required at least two to three hours extra time for each group. As there are eight groups, this amounted to an additional time of twenty four hours to implement the whole life cycle group work.

B. Comparison of loosely coupled and closely coupled Software Tools

Generally, loosely coupled SWT did not have any significant impact on the students who participated in it. During summer semester 2007, 32 from 74 students participated in SWT. However, closely coupled SWT made significant impact on ES2 grade for the students who participated in it. The average grade for students who participated in SWT in summer semester 2008 was 2.28 as compared to 3.05 for those who did not. The result for summer semester 2009 also supported the observation where closely coupled SWT has more impact and the approach had significant influence on the participants. The students who

TABLE V COMPARISON OF PARTICIPANTS AND NON PARTICIPANTS FOR SOFTWARE TOOLS

Software Tools			Participants			Non-Participant			Significance
			N	Average	Std. Dev.	N	Average	Std. Dev.	
Computer Science	LC SWT	SS 2007	10	3,200	0,7409	40	3,238	1,0081	0,913
	CC SWT	SS 2008	2	3,150	2,6163	43	3,312	1,2236	0,862
	CC SWT	SS 2009	7	3,857	1,0830	49	3,286	1,2057	0,241
Mecha-tronics	LC SWT	SS 2007	22	3,350	1,0541	2	4,500	0,7071	0,149
	CC SWT	SS 2008	24	2,583	1,2761	3	4,333	0,5774	0,029
	CC SWT	SS 2009	22	2,532	1,2029	2	5,000	0,0000	0,009

participated in SWT had 2.021 average grades, whereas those did not, only have 2.763.

TABLE VII COMPARISON OF PARTICIPANTS AND NON PARTICIPANTS FOR GROUP WORK

Group Work			Participants			Non-Participant			Significance
			N	Average	Std. Dev.	N	Average	Std. Dev.	
Computer Science	GW-Partial	SS 2007	41	3,029	0,8878	9	4,144	0,6966	0,001
	GW-Whole	SS 2009	34	3,659	1,0252	22	2,891	1,3140	0,018
Mecha-tronics	GW-Partial	SS 2007	16	3,544	0,9906	8	3,250	1,2581	0,537
	GW-Whole	SS 2009	22	2,532	1,2029	2	5,000	0,0000	0,009

Table VIII separates the Computer Science students from the Mechatronics. A few trends can be observed here. Firstly, the participation from Mechatronics students was higher as it was a compulsory course for them. Secondly, there was no significant difference if the Computer Science students participated in SWT or not. Thirdly, closely coupled SWT positively influenced the Mechatronic students' result. The ES2 result between those who took part in closely coupled SWT was significantly better than those who did not.

Generally, students who participated in SWT had better average grades than those who did not. The average grades for loosely coupled SWT were poorer than the control data. However, tightly coupled SWT's average for both Computer Science and Mechatronics was better than the control data average.

IX. CONCLUSION

In this paper different active learning methods for a large interdisciplinary class were introduced analyzed. There were three challenges presented in section IIB, namely – students from different disciplines have different cognitive mindset, it is difficult to engage students in a large class setting, and the limited teaching resources.

To the point different cognitive mind set the following points are summarized:

- The pop quizzes benefitted both Computer Science students and Mechatronics students.
- The Computer Science students prefers partial life cycle group work as it requires less time and effort as compare to the whole life cycle group work.
- The Mechatronics students on the other hand are willing to put in the effort required by whole life cycle group work and benefitted more as compared to the Computer Science students.

In order to engage the students in a large class setting, it is important to involve the students. Simple methods like round robin questioning, in class demonstration and "throwing tissue pack" should be implemented. Preparing good nice slides or explaining the slides in details is not sufficient to draw the students' attention.

In order to reduce the effort required to conduct the course, implementation of the same bench scale equipment for the different subjects is recommended. Apart from this, coupling with another course is another possibility to win new resources for the course.

Table IX summarizes the effort needed and the effectiveness of the different methods. "Pop quizzes" is a winner, followed by closely coupled software tools. Pop quizzes prepare the students to answer the exam questions for the final exam. However, one weakness with pop quizzes is the students do not get to implement the theory. In SWT, the students are able to implement the theory they learnt in ES2 in a software tool. The effort required to closely couple with another course is not high in term of man-hours but the two co-ordinators need to be in constantly exchange feedback concerning what was being taught and what difficulties faced by the students. Depending on the available resources and the participants in the class, one can select the most suitable method for the class using Table IX.

TABLE VI EFFORTS REQUIRED AND EFFECTIVENESS OF THE DIFFERENT METHODS

Method	Effort	Effect	
		CS	M
Round Robin questioning	Low	+	
In class demonstration with students' participation	Low	+	
Throwing tissue pack to students	Low	+	
Implementation of bench scale equipment	Low	+	
Pop quizzes	4 hrs + n(30 mins)	++	++
Partial life cycle group work	2 hrs + n(8 hrs)	++	-
Whole life cycle group work	2 hrs + n(24 hrs)	--	++
Loosely coupled software tools	2 hrs	-	+
Closely coupled software tools	3 hrs	o	++

++ significantly good — - poor
+ good — -- significantly poor
o no visible impact — n = number of group with 40 students

For teaching Embedded System in a large class environment, especially with participants from Computer Science and Mechatronics students, it is recommended to implement pop quizzes and closely coupled software tools. Pop quizzes significantly benefits both Computer Science and Mechatronics students in their exam. Closely coupled SWT provides the opportunity to implement the theory learnt in ES1, and has more impact than loosely coupled SWT.

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Cooperative Learning vs. Project Based Learning

a practical case

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Abstract— **The Bologna Declaration and the implementation of the European Higher Education Area are promoting the use of active learning methodologies such as cooperative learning and project based learning. This study was motivated by the comparison of the results obtained after applying Cooperative Learning (CL) and Project Based Learning (PBL) to a subject of Computer Engineering. The fundamental hypothesis tested was whether the academic success achieved by the students of the first years was higher when CL was applied than in those cases to which PBL was applied.**

A practical case, by means of which the effectiveness of CL and PBL are compared, is presented in this work. This study has been carried out at the Universidad Politécnica de Madrid, where these mechanisms have been applied to the Operating Systems I subject from the Technical Engineering in Computer Systems degree (OSIS) and to the same subject from the Technical Engineering in Computer Management degree (OSIM). Both subjects have the same syllabus, are taught in the same year and semester and share also formative objectives.

From this study we can conclude that students' academic performance (regarding the grades given) is greater with PBL than with CL. To be more specific, the difference is between 0.5 and 1 point for the individual tests. For the group tests, this difference is between 2.5 and 3 points. Therefore, this study refutes the fundamental hypothesis formulated at the beginning. Some of the possible interpretations of these results are referred to in this study.

Collaborative work; Education; Engineering Education

I. INTRODUCTION

"On 28 and 29 April 2009, the Ministers responsible for higher education in the 46 countries of the Bologna Process met in Leuven and Louvain-la-Neuve to establish the priorities for the European Higher Education Area until 2020. They highlighted in particular the importance of lifelong learning, widening access to higher education, and mobility" [1]. They emphasized as well on the significance of Student-centered learning and the teaching mission of higher education. "Student-centred learning requires empowering individual learners, new approaches to teaching and learning, effective support and guidance structures and a curriculum focused more clearly on the learner in all three cycles" [2]. New active learning methodologies such as Cooperative Learning (CL) and Project Based Learning (PBL) are found among the new approaches adopted in teaching and learning.

Cooperative learning is the instructional use of small groups so that students work together to maximize their own and each other's learning [3], [4]. In this work CL has been applied with the jigsaw technique [5]. The comparison, between the effectiveness of CL and the lecture/discussion method in higher education, has been examined in several studies [3], [6]-[8]. PBL has been established in the field of engineering as a significant experience which promotes cognitive activities and long-life learning [9]-[12].

The Educative Innovation Group DMAE-DIA [13] of the Universidad Politécnica de Madrid has been using active learning methodologies such as CL and PBL [14]-[18] for several years. This group is aimed at: 1) achieving a more active students´ participation in the learning/teaching process; 2) improving student's academic performance by promoting specific competences and 3) developing new learning and assessment methodologies.

A practical case, by means of which the effectiveness of CL and PBL are compared, is presented in this work. This study has been carried out at the Universidad Politécnica de Madrid, where these mechanisms have been applied to the subject Operating Systems I of the degree in Technical Engineering in Computer Systems (OSIS) and to the same subject of the degree in Technical Engineering in Computer Management (OSIM). The aim of the study is to compare the advantages and disadvantages of CL and PBL when applied to Engineering. Among the criteria to be compared we can find: 1) the academic performance of students; 2) the drop-out rate and the time in which it took place; 3) the opinion of students with regard to different aspects of the subjects: assessment methodologies, teaching methodologies adopted or the level of difficulty of the subjects studied.

As far as we are concerned, no studies of this nature which make a comparison between CL and PBL have been published. There are, however, some publications which differentiate between Project Based Learning and Problem Based Learning [19], [20], between Problem Based Learning and the traditional educational methodology [21], [22] as well as between CL and the traditional development of lectures [6], for instance. Hence the importance of this study, due to its originality.

The hypothesis of work is that the academic success achieved by students would be higher when CL is applied to the subject than in those cases in which PBL is applied. Two reasons support this idea: 1) The lack of maturity noticed in students during the first year to organize learning by themselves; 2) CL (as a "jigsaw") entails a more directed learning process than PBL. Therefore, a better academic performance is expected.

This paper is structured as follows: the number of participants who took part in the study, the teaching practice developed and the way in which data analysis was carried out are described in section 2. Section 3 presents the study results as well as a discussion about them. Section 4 is used to make a brief description of an experience in which both methodologies (CL and PBL) where combined and applied to two subjects of Computer Engineering. Finally, the main conclusions of this work are presented in section 5.

II. METHOD

A. Participants

This study has been carried out at the Universidad Politécnica de Madrid, where CL and PBL have been applied to Operating Systems I subject of the degree in Technical Engineering in Computer Systems (OSIS) and to the same subject of the degree in Technical Engineering in Computer Management (OSIM). Both subjects have the same syllabus, are taught in the same course and semester and share also formative objectives. The latter syllabus, OSIM, has been taught applying PBL to a group of 60 students, who were put together into an only group. The former, OSIS, has been taught applying CL to 107 students, who were divided into two groups. The three professors who have taught these subjects are highly experienced both in teaching the subjects and in using CL and PBL.

B. Procedure

Both subjects, OSIS and OSIM, are broken down into five topics: Introduction, Process and Threads, Memory Management, Input/Output and File Systems. Students had only one book of reference [23] to meet all these topics. Both subjects, OSIS and OSIM, were taught for 15 weeks, with two-hour sessions per week.

In the subject SOIM the tasks which constitute the project will be carried out by groups of 4 or 5 students. This project is aimed at making a comparison between the operating systems Windows XP and Linux along the course, regarding the aspects included in the syllabus of the subject. At the end of the term, students should be able to explain a series of essential differences and similarities between both operating systems, from the point of view of their interface, implementation and performance. The project will be divided into 4 tasks. Students will tackle a different topic in each of the works, which will be related to the contents of the syllabus. The professor will suggest a series of topics; however, any group can work on another topic suggested by them, which has to be previously agreed with the professor. The development of each topic consists of three phases. First, students carry out a search and study of information. Then, they have to design an experiment approaching the comparison between Linux and Windows XP, with regard to the topic studied. Finally, they present a report with all the work carried out, including the results obtained in the experiment, and also make an oral presentation. At the end of the term, a debate is established focusing on all the projects developed by students in order to answer a series of open questions: Are Linux and Windows XP actually so different? Is there any significant difference regarding their performance? Does any of the operating systems offer more advantages from the point of view of programming?

On the other hand, CL was applied to the fifteen OSIS sessions. At the beginning of the course, permanent groups of four students (base groups) were formed. Because of CL, each member of a group had to be an expert on some basic concepts of the topic during each session. For this reason, the homework students were given depended on the type of expert. There were four kinds of homework, one addressed to each expert. For each session, this homework was structured into three parts: the first described the learning objectives and skills to be acquired with the homework; the second indicated the information to be studied, and the third part consisted in solving basic problems, developing a simple program or answering some questions. Both the second and the third part were set estimated periods of time to be carried out. Homework had to be handed to the professor before the session in question started and the real amount of time it took them to do it must be indicated. Along each session, CL method was put into practice and all base groups tried to solve a problem which required the knowledge of the four experts (jigsaw). At the end of the session there was a global discussion about the difficulties encountered and the different ways to solve the problems.

C. Measurements and instruments

Three different types of measurements were used: the ones corresponding to academic performance, the ones relative to the drop-out rate and those regarding the opinion survey responded by students.

- Academic performance. It is considered as the set of grades achieved along the semester. Both grades, the ones achieved in specific tests of each methodology (group grades) and those grades achieved in multiple-choice exams (individual grades) are taken into account.

In the subject OSIM the final grade consists of two parts: an individual mark (50%) and a group mark (the mark obtained in the project carried out in group, 50%). Individual marks are made up of 4 tests (20%), some questionnaires with short questions (10%) and problem solving activity (20%). Each part of the project is assessed in two ways: 1) Co-assessment (50%) - each group has to assess the work carried out by the other groups as well as to classify them regarding their quality. Students are awarded a grade according to the mark they have been given and to the position reached in the ranking; 2) Professor's assessment (50%) - the professor makes a correction of each students' assessment and awards them the remaining 50% of the grade. In order to carry out these two assessments, rubrics with the criteria to be considered are provided for each of them. These rubrics are at students' disposal so that they are aware of the criteria demanded before carrying out every phase of the project.

In the subject OSIS a continuous assessment method was followed so as to evaluate achieved specific competences of the subject. During the course, four different kinds of activities were used, all of which were assessed: lab exercises, tests, CL and individual homework. The final grade consists of two parts: an individual mark (40%) and a group mark (60%). Individual marks are made up of 5 tests (20%), and 3 individual assessments (20%). Group marks are made up of 6 assessments (40%) and 5 lab exercises (20%). The individual assessments consisted in carrying out a short question or exercise which had been chosen from the homework of the session. Some of the tests and individual assessments were assessed by other classmates (peer-evaluation). In order to pass the course, students must achieve a minimum grade of 50% and at least a third must be achieved in each evaluated part.

- Drop-out. The drop-out rate and the time in which it took place are considered, as well as their relationship to the different phases of implementation of both methodologies.

At the beginning of the OSIM course, 39 out of 60 students started the project. These students were divided into 9 groups. These groups handed in the first of the four topics of which the project was constituted, although two groups (a total of 9 students) dropped out before submitting the second task and stopped attending classes. One of them had been awarded a low grade in the assignment they had handed in, while the other group achieved a considerably high grade (7.6 out of 10).

In the subject OSIS, the total number of students who dropped out the course was 27. During the first topic, which took four sessions, 18 students dropped out because they realized they were not able to dedicate 110 hours making a continuous effort for 15 weeks. The remaining drop-outs took place at the end of each topic; the rate was significantly lower at that moment, though, since only three students drop the course out after topics 2 and 3, two students after topic 4 and just one student after topic 5.

Therefore, the fact that most of the drop-outs, both with PBL and CL, took place during the first month of the course can be inferred from the information given above. The hypothesis considered is that students notice during the first month the workload required by the subject and consider whether they would be able or not to devote the time needed. However, more data are necessary in order to confirm the hypothesis.

- Opinion survey. At the end of the term, students respond to an opinion survey with questions about specific aspects studied along the course. In this section, the most important results obtained from the students' opinion are shown. Questions directly related to the contents of the course were excluded. In the first block, we asked four questions regarding the effectiveness of each methodology. Students' opinion is indicated below in a scale which ranges from 1 to 5:

1.- I consider the level of difficulty of the matters raised in the tests according to the themes studied in class to be:

	OSIM	OSIS
5.- Very difficult	12 %	22 %
4.- Quite difficult	64 %	53 %
3.- Appropriate	16 %	20 %
2.- Quite easy	8 %	3 %
1.- Very easy	0 %	2 %

2.- On the whole, I think that I have learnt a lot about operating systems and this knowledge will be permanent to a large extent:

	OSIM	OSIS
5.- Totally agree	16 %	6 %
4.- Quite agree	32 %	36.5%
3.- Agree	40 %	39 %
2.- Quite disagree	8 %	12.5%
1.- Totally disagree	4 %	6 %

3.- In general, I believe that PBL/CL methodology has helped me understand better and acquire deep knowledge of the concepts:

	OSIM	OSIS
5.- Totally agree	4 %	6 %
4.- Quite agree	40 %	39 %
3.- Agree	44 %	35 %
2.- Quite disagree	12 %	15 %
1.- Totally disagree	0 %	5 %

4.- Regarding the level of difficulty when it comes to understand the texts to be studied without any previous explanation, I find it:

	OSIM	OSIS
5.- Excessively high	4 %	16 %
4.- High	28 %	51 %
3.- Appropriate	60 %	28 %
2.- Low	0 %	5 %
1.- Really low	8 %	0 %

Two questions related to the assessment strategies followed were made in order to know students' opinion about their effectiveness.

1.- The results obtained are a reflection of the personal effort I have made:

	OSIM	OSIS
5.- Totally agree	4 %	4 %
4.- Quite agree	16 %	26 %
3.- Agree	24 %	33 %
2.- Quite disagree	48 %	30 %
1.- Totally disagree	8 %	7 %

2.- On the whole, I think that the assessment method used is better than the conventional, which was only based on the final test.

	OSIM	OSIS
5.- Totally agree	48 %	39 %
4.- Quite agree	24 %	33 %
3.- Agree	16 %	24 %
2.- Quite disagree	12 %	1 %
1.- Totally disagree	0 %	3 %

D. Data Analysis

For the Statistical Analysis we used version 5.1 of the statistical program STATGRAPHICS. The statistical techniques for the analysis were: for the distribution fitting to determine if data can be adequately modelled by a normal distribution we used Kolmogorov_Smirnov test and superimposed the PDF of the fitted normal distribution. We run F-Snedecor test to decide whether the equality of variances must rejected. We run a t-test with an m+n-2 freedom degree to decide if the equality of the means could be considered in those cases in which the equality of variances could not be rejected and the Welch approximation was ran whenever the equality of variances had been rejected. To decide whether the equality of percentages must be rejected or not, we run a Hypothesis Test for Difference Between Proportions.

III. RESULTS AND DISCUSSION

We carried out a comparison of the grades in both methodologies.

A. Analysis of the grades achieved in the test with PBL and CL methodologies

The first step was to conduct an exploratory examination of the data. This was carried out both analytically and graphically. We used the statistical software Statgraphics. Table I shows some statistics. GTEST_G variable corresponds to the subject OSIM, while STEST_G variable refers to the subject OSIS. Fig. 1 shows the histogram and density estimated [24] for the test grades achieved in OSIM, to which PBL methodology had been applied. Fig. 2 shows the histogram and density estimated for the test grades achieved in OSIS, to which CL methodology had been applied.

The results of the test ran in order to determine whether GTEST_G and STEST_G can be adequately modelled by a normal distribution are shown. The Kolmogorov-Smirnov test has been performed.

Tests for Normality for GTEST_G

Kolmogorov-Smirnov test
Estimated overall statistics DN=0.0770702
Approximate P-Value = 0.99281

Tests for Normality for STEST_G

Kolmogorov-Smirnov test
Estimated overall statistics DN=0.0869847
Approximate P-Value = 0.357309

Since in the test which has been carried out the computed P-value is not less than 0.05, the null hypothesis that STEST_G and GTEST_G come from a normal distribution with a 0.05 level was not rejected.

TABLE I. SUMMARY STATISTICS

	GTEST_G	STEST_G
Count	31	114
Average	4.89032	3.79737
Median	4.6	3.9
Mode	4.1	4.6
Variance	3.58424	2.73282
Standard deviation	1.89321	1.65313
Minimum	0.8	0.0
Maximum	8.7	8.5
Range	7.9	8.5
Lower quartile	3.7	2.9
Upper quartile	6.1	4.7
Skewness	-0.0181856	-0.208458

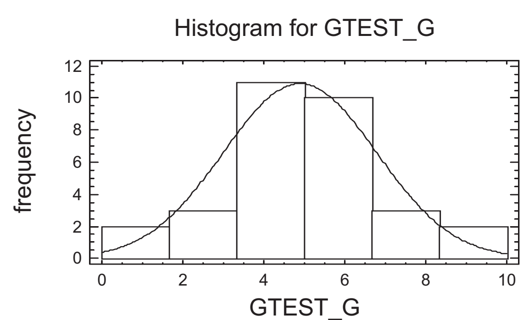

Figure 1.

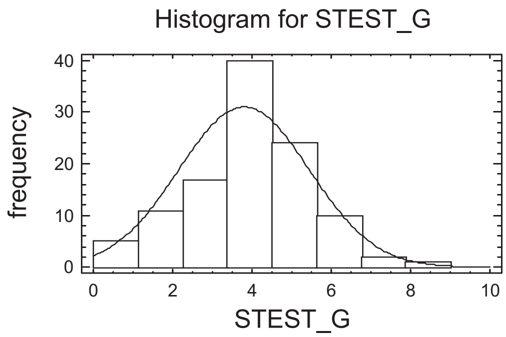

Figure 2.

After that, a comparison of GTEST_G and STEST_G, the two teaching methods for OSIM and OSIS, was carried out. Fig. 3 shows the box-plot of the data.

They turn out to be different. The length and the interquartile ranges of the group GTEST_G are not similar to those of the group STEST_G. The data of the groups GTEST_G and STEST_G were modelled as realizations of random samples X1, X2,…, Xm and Y1, Y2,...,Yn with m=31 and n=114 from two distributions: one with the expected value $\mu 1$ and the other with the expected value $\mu 2$; the hypothesis of the test was: H0: $\mu 1=\mu 2$ against H1: $\mu 1\neq\mu 2$.

First, we had to decide whether there is a statistically significant difference between the standard deviations of the two samples. An F-test [25] was ran so as to compare standard deviations. In this case: H0: $\sigma 1=\sigma 2$ against H1: $\sigma 1\neq \sigma 2$. Since the computed P-value is not less than 0.05, the equality of variances cannot be rejected. These results are shown in Table II.

Then, a t-test was carried out to compare the means of the two samples. A t-test was used: $H_0:\mu_1=\mu_2$ against $H_1:\mu_1\neq\mu_2$. Since the computed P-value is less than 0.05, the null hypothesis can be rejected in favour of the alternative. These results are shown in Table III.

As the confidence interval is as well shown for the difference of means (confidence 0.95), the following tests can be considered according to this. A t-test was run once again. In this case: $H_0:\mu_1-\mu_2 \leqslant 0.5$ against $H_1:\mu_1-\mu_2>0.5$. Since the computed P-value is lower than 0.05, the null hypothesis was rejected. Thus, we have to admit that there is a considerable difference with a 0.05 significance level between the means of the grades in GTEST_G and STEST_G, which is 0.5 points greater than. These results are shown in Table IV.

Finally, a t-test was performed again. In this case, the test had been carried out to determine whether the difference between the two means is equal or less than 1, versus the alternative hypothesis which states that the difference is greater than 1. $H_0:\mu_1-\mu_2\leqslant 1$ against $H_1:\mu_1-\mu_2>1$. Since the computed P-value is not less than 0.05, the null hypothesis cannot be rejected. Then we have to admit with a 0.05 level that there is a significant difference between the means of the grades of the test performed in the two groups, and the idea that the difference between the grades in GTEST_G and STEST_G is lower than 1 point cannot be rejected. These results are shown in Table V.

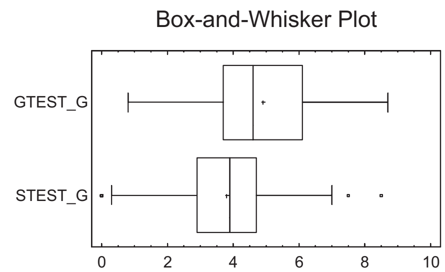

Figure 3.

TABLE II. COMPARISON OF STANDARD DEVIATIONS

	GTEST_G	STEST_G
Standard deviation	1.89321	1.65313
Variance	3.58424	2.73282
Df	30	113

Ratio of Variances = 1.31155

F-test to Compare Standard Deviations

Null hypothesis: sigma1 = sigma2
Alt. hypothesis: sigma1 NE sigma2
F = 1.31155 P-value = 0.312464

NOTE: these results assume that the distributions of the two samples can be adequately modelled by a normal distributions.

TABLE III. COMPARISON OF MEANS

95,0% confidence interval for the difference between the means assuming equal variances: 1.09295 +/- 0.683195 [0.409759,1.77615]

t test to compare means
Null hypothesis: mean1 = mean2
Alt. hypothesis: mean1 NE mean2
assuming equal variances: t = 3.16226
P-value = 0.00191215

TABLE IV. COMPARISON OF MEANS

t test to compare means
Null hypothesis: mean1 - mean2 = 0.5
Alt. hypothesis: greater than
assuming equal variances: t = 1.7156
P-value = 0.0442005

TABLE V. COMPARISON OF MEANS

t test to compare means
Null hypothesis: mean1 - mean2 = 1.0
Alt. hypothesis: greater than
assuming equal variances: t = 0.268945
P-value = 0.39418

These results consider the variances of the two samples to be equal. In this case, that assumption appears to be reasonable based on the results of an F-test which was carried out to compare the standard deviations (Table II).

To summarize, we have to admit that the grades achieved in the test with GTEST_G are greater than the grades achieved in the test with STEST_ G, between 0.5 and 1 point. Significance level: 0.05.

B. Analysis of the grades achieved in students group works with PBL and CL methodologies

A comparison on the grades in both methodologies was carried out. Therefore, the same steps than in the case of the comparison of the grades achieved in the test were followed. The first step was to carry out an exploratory examination of the data. Table VI shows some statistics.

Fig. 4 shows the histogram and density estimate of the grades achieved in OSIM, and Fig. 5 shows the histogram and density estimate of the grades achieved in OSIS.

The results of the Kolmogorov-Smirnov test performed in order to determine whether GGroup_G and SGroup_G can be adequately modelled by a normal distribution are shown.

Since in every test carried out the computed P-value is not lower than 0.05, the null hypothesis that GGroup_G and SGroup_G come from a normal distribution with 0.05 level was not rejected.

Next, a comparison between GGroup_G and SGroup_G, the two teaching methods for OSIM and OSIS, was carried out. Fig. 6 shows the box-plot of the data.

Tests for Normality for GGroup_G

Kolmogorov-Smirnov test
Estimated overall statistic DN = 0.211216
Approximate P-Value = 0.125848

Tests for Normality for SGroup_G

Kolmogorov-Smirnov test
Estimated overall statistic DN = 0.123826
Aproximate P-Value = 0.0606438

They turn out to be different. The length and the interquartile ranges of the group GGroup_G are not similar to those of the group SGroup_G. The data of the groups GGroup_G and SGroup_G were modelled as realizations of random samples $X_1, X_2, ..., X_m$ and $Y_1, Y_2, ..., Y_n$ with m=31 and n= 114 from two distributions; one with the expected value μ_1 and the other with the expected value μ_2; the hypothesis of the test was: H_0: $\mu_1=\mu_2$ against H_1:$\mu_1 \neq \mu_2$.

TABLE VI. SUMMARY STATISTICS

	GGroup_G	SGroup_G
Count	31	114
Average	7.62258	4.34737
Median	7.4	4.7
Mode		
Variance	0.445806	3.1142
Standard deviation	0.667687	1.76471
Minimum	5.5	0.0
Maximum	8.6	7.7
Range	3.1	7.7
Lower quartile	7.3	3.7
Upper quartile	8.1	5.4
Interquartile range	0.8	1.7
Skewness	-0.81226	-0.558472
Coeff. Of variation	8.75934%	40.5926%

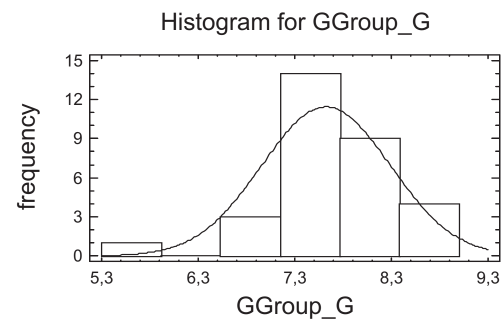

Figure 4.

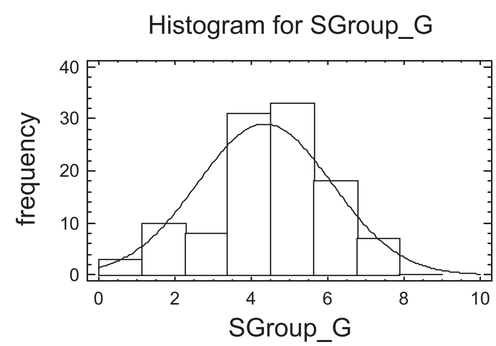

Figure 5.

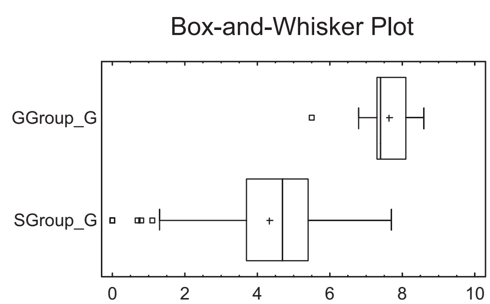

Figure 6.

First, we had to decide whether there is a statistically significant difference between the standard deviations of the two samples. An F-test was run so as to compare standard deviations. In this case: H0: $\sigma 1 = \sigma 2$ against H1: $\sigma 1 \neq \sigma 2$. Since the computed P-value is less than 0.05, the equal of variances can be rejected. These results are shown in Table VII.

Then, a t-test was carried out to compare the means of the two samples. A t-test was used: H0:$\mu 1=\mu 2$ against H1:$\mu 1 \neq \mu 2$. Since the computed P-value is less than 0.05, the null hypothesis in favour of the alternative can be rejected. These results are shown in Table VIII.

As the confidence interval is as well shown for the difference of means (confidence 0.95), the following tests can be considered according to this (Table VIII).

A t-test was run again. In this case: H0:$\mu 1-\mu 2 \leqslant 2.5$ against H1:$\mu 1-\mu 2>2.5$. Since the computed P-value is less than 0.05, the null hypothesis was rejected. Then we have to admit that there is a considerable difference with a 0.05 significance level between the means of the grades in GGroup_G and SGroup_G, which is greater than 2.5 points. These results are shown in Table IX.

Finally, another t-test was carried out. In this case, the test had been constructed in order to determine whether the difference between the two means is equal or less than 3, versus the alternative hypothesis which states that the difference is greater than 3. H0:$\mu 1-\mu 2 \leqslant 3$ against H1:$\mu 1-\mu 2>3$.

Since the computed P-value is not less than 0.05, the null hypothesis cannot be rejected. Then we have to admit with a 0.05 level that there is a significant difference between the means of the grades achieved by two groups in the test, and the idea that the difference between the grades achieved in GGroup_G and in SGroup_G is less than 3 points cannot be rejected. These results are shown in Table X.

These results consider the variances of the two samples to be not equal. In this case, that assumption appears to be reasonable based on the results of an F-test which was carried out to compare the standard deviations (Table VII). Different tests were performed for the Two-Sample Comparison, although one P-value was near 0.5 considering that the absence of normality has normally no influence on the F-test run by ANOVA and in the comparison of means [25].

To conclude, we have to admit that the grades achieved in GGroup_G are greater than the grades achieved in SGroup_G, between 2.5 and 3 points. Significance level: 0.05.

C. *Analysis of the opinion survey*

We had to decide whether there is a statistically significant difference between the percentages of the opinion survey answers given by the students of both methodologies. In this case we used an statistic T whose distribution is approximately N (0,1). We noted t the value of this statistic assuming equal proportions.

Relating to question 1 ("I consider the level of difficulty of the matters raised in the tests according to the themes studied in class to be: very difficult, quite difficult, appropriate, quite easy or very easy") we obtained the comparison of proportion shown in Table XI.

TABLE VII. COMPARISON OF STANDARD DEVIATIONS

	GGroup_G	SGroup_G
Standard deviation	0.667687	1.76471
Variance	0.445806	3.1142
Df	30	113

F-test to Compare Standard Deviations

Null hypothesis: sigma1 = sigma2
Alt. hypothesis: sigma1 NE sigma2
F = 0.143153 P-value = 6.71803E-8

TABLE VIII.

Two-Sample Comparison - GGroup_G & SGroup_G

Comparison of Means

95,0% confidence interval for the difference between the means not assuming equal variances: 3.27521 +/- 0.404024 [2.63468,3.91575]

t test to compare means

Null hypothesis: mean1 = mean2
Alt. hypothesis: mean1 NE mean2
not assuming equal variances: t = 16.0391
P-value = 0.0

TABLE IX.

Two-Sample Comparison - GGroup_G & SGroup_G

Comparison of Means
----

t test to compare means

Null hypothesis: mean1 - mean2 = 2.5
Alt. hypothesis: greater than
not assuming equal variances: t = 3.7963
P-value = 0.000112408

TABLE X.

Two-Sample Comparison - GGroup_G & SGroup_G

Comparison of Means
----

t test to compare means

Null hypothesis: mean1 - mean2 = 3.0
Alt. hypothesis: greater than

not assuming equal variances: t = 1.34775 P-value = 0.0900526

In Table XI, P1* y P2* are the proportion of students who answered appropriate, quite difficult or very difficult in OSIM and OSIS respectively and p* is the pooled proportion. Since the value obtained (assuming H0) is t = -0.7371, greater than -1.96 and less than 1.96, values from the Normal distribution for α=0.05, the null hypothesis cannot be rejected for this significance level. Similar results have been obtained in questions 2 (t= 1.11836) and 3 (t = 0.2835). Therefore we have to admit that the percentages of the answers given follow very similar criteria and no significant differences can be established regarding the assessment made by students of both subjects. It has to be highlighted that students have a good opinion about the methodologies applied to both subjects and believe to have acquired a deep knowledge in the two of them.

Relating to question 4 ("Regarding the level of difficulty when it comes to understand the texts to be studied without any previous explanation, I find it: Excessively high, high, appropriate, low or really low") we obtained the comparison of proportion shown in Table XII.

In Table XII, P1* y P2* are the proportion of students who answered appropriate, low or really low in OSIM and OSIS respectively. Since the value obtained from the statistic (assuming H0) is t=3.2157 greater than 1.65, value from the normal distribution for α=0.05, the null hypothesis must be rejected for this significance level. Therefore we have to admit that the percentage of students who answered appropriate, low or really low is greater in OSIM than the percentage of students who answered appropriate, low or really low in OSIS. In this respect, it is worth pointing out that some master classes have been programmed in order to help with the development of the subject OSIM; some basic theoretical issues were taught during these classes before the beginning of the student work. However, students had to deal with the study of OSIS before the subject had started.

TABLE XI.

Comparison of Proportions OSIM OSIS -- P_1* = 0.92 P_2* = 0.9557 p*= 0.9493 Null hypothesis: P_1 = P_2 Alt. hypothesis: P_1 NE P_2 Assuming H_0 the value of T: t= -0.7371

TABLE XII.

Comparison of Proportions OSIM OSIS -- P_1* =0.68 P_2* = 0.3302 p*=0.3969 Null hypothesis: P_1 = P_2 Alt. hypothesis: P_1 greater than P_2 Assuming H_0 the value of T: t= 3.2157

Concerning the two questions related to the assessment strategies, the comparison of proportions produced t = -1.7244 (question 1) and t = -1.6452 (question 2). Since these values of the statistic are greater than -1.96 and less than 1.96 , values from the Normal distribution for α=0.05, the null hypothesis (P1 = P2) cannot be rejected for this significance level. Consequently, we have to admit that students of both subjects seem to fully agree with the fact that the assessment method used is better than the conventional one, in which 80% of the grade was achieved in a final exam (the remaining 20% was achieved after carrying out some practical activities).

IV. AND, WHY NOT TO COMBINE CL AND PBL?

In spite of the fact that CL and PBL have proved to be useful regarding the meaningful learning acquired by our students, it is necessary to combine them at some point in order to reach an effective learning process. While an experiment was performed in order to make a comparison between CL and PBL in the Operating System subject, another experiment which combined both methodologies was conducted meanwhile, during the same course. Such experiment was tried in two subjects. The first experience was carried out in the subject Real Time Systems of the degree in Technical Engineering in Computer Systems at the Universidad Politécnica de Madrid; the second, in the subject Software Engineering II of the degree in Technical Engineering in Computer Systems at the Universidad Rey Juan Carlos. These subjects were taught adopting a PBL methodology in both cases. The experience acquired in the last years has proved to increase students' motivation for studying the subject when PBL is applied. On the other hand, with the implementation of PBL students have slightly relaxed when it comes to deal with the theoretical study of some aspects which are essential for the development of the project, though. In these cases, the role of the professor as the leader and supervisor of acquiring learning (as it is suggested by the PBL methodology) is not enough. In turn, it seems to be more effective if individual learning sessions are turned into active learning by means of the implementation of CL, for instance [26].

In the subject Real Time Systems the development of the project is carried out by teams of three students. We scheduled two CL sessions in which all the members of a team worked together in order to solve a problem related to their project. Each session lasted for 110 minutes. One session was designed to work on the last two chapters of the course which were not covered by the development of the project (Fault Tolerance and High Integrity Systems). At the end of the session, a small problem was proposed to every team. The second session was designed with a different purpose: helping students when it comes specifically to develop a critical phase of the project. In this phase, students have to do a creative design work. It is very important to know clearly the theoretical concepts on which this task is based in order to be able to use them, so students should avoid relaxing in the theoretical study. Furthermore, it is advisable to have the professor supervise the design while students are carrying it out, as well as hold a debate with them to discuss the proposed solution. The result of this task has a great influence on the complexity which they will find in the development of further phases of the project. That is why achieving a certain level of quality in their design is so important. CL was applied to both sessions as a jigsaw [5]. Besides, by improving the team-working skill, these self-contained sessions turned out to be really helpful in order to complete the topics included in the syllabus and to overcome the critical phases of the project. Students showed enough knowledge in both cases. Moreover, this educational methodology was favourably welcomed by students. A 60% of them strongly agreed with the following statement: "Cooperative Learning is a helpful methodology to learn the contents of the subject" in an opinion survey which was carried out at the end of the course. A 27% of students simply agreed with this assertion and the remaining 13% disagreed.

In the subject Software Engineering II the project is carried out by teams of four students along 30 sessions of 2 hours each. As it is said above, applying CL helps us to avoid students relax when it comes to study the concepts which are not covered by the project. However, CL can as well be a way to guide and supervise students in the autonomous learning progress required by PBL. In this subject, for example, students must learn JAVA (they can program, but they do not know the language). In order to guide students, the professor schedules 8 CL sessions which last 110 minutes each. Different aspects of the language are studied in every session. At the end of the session, the team has to develop a program. This way the professor is able to guide the study of the elements of the language and to supervise students' learning regarding the quality of their program. Another important topic are testing methods. Although there are several testing methods, students will only use two or three of them in order to test their project. A CL session of 110 minutes is scheduled in order to force students to study and use each method at least once. This session allows the professor to guide and supervise the work of students. The professor guides them when it comes to selecting some literature which they must analyse and study. After the session every team has to prepare a collection of test cases using the different testing methods. Furthermore, an individual test is also carried out. Thus, the professor is able to supervise the individual learning process. In this subject the sessions are structured as a jigsaw, just like in the RTS course. In this case the educational methodology was favourably welcomed by students too.

V. CONCLUSION

As it can be inferred from the results above, the work hypothesis cannot be proved. The lack of maturity of the students from the third term was one of the reasons that made us think of the idea that CL would give as a result a better academic performance. However, we have observed that students' performance is not affected by their lack of maturity when PBL methodology is supported by individual tuition addressed to each group of work. On the other hand, as it has been already proved in further studies [16], one of the advantages of PBL methodology is the increase in students' motivation, a fact that could be stated by OSIM professors. We are of the opinion that this aspect may have had a great influence on the academic results achieved. From our point of view, there are two possible ways of verifying this conclusion. First, another study should be carried out in order to calculate the different level of motivation among students from both methodologies and to establish a relationship to their academic performance. Second, we think that the study carried out in this work should be applied to other subjects and to different contexts so as to corroborate the results obtained.

ACKNOWLEDGMENT

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Session 09C Area 1: Collaborative and Social Technologies - Collaborative and projects works

Distributed Collaborative Homeworks: Learning Activity Management and Technology Suppor

Borge, Marcela; Carroll, John M.; Ganoe, Craig; Jiang, Hao
The Pennsylvania State University (United States of America)

Tools for Collaborative Development of Visual Models and Languages

Allert, Heidrun; Richter, Christoph; Tchoumatchenko, Vassiliy Platonovitch; Vasileva, Tania Krumova
Technical University of Sofia (Bulgaria)

Embedding Sustainability in Capstone Engineering Design Projects

Hasna, Abdallah
The University of Southern Queensland (Australia)

Project-Based Collaborative Learning of Electrical Master Students

Raud, Zoja; Vodovozov, Valery
Tallinn University of Technology (Estonia)

Distributed Collaborative Homeworks

Learning Activity Management and Technology Support

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***Abstract*— We describe use of partially distributed collaborative assignments in a Usability Engineering course with respect to (1) learning activity management and (2) technology support.**

Keywords- collaborative learning, case-based learning, collaborative software, learning technoloy, usability engineering

I. Introduction

The engineering students of today will most likely work in partially distributed teams during their careers, as network mediated collaboration becomes more routine. During the past three years, we have been experimenting with partially distributed team assignments in an upper-level undergraduate course in usability engineering at the Pennsylvania State University (Penn State). These assignments employ *case-based learning* [Carroll & Rosson, 2005; Jiang et al., in press]: students analyze and apply ideas from online case studies documenting real-life professional practices in usability engineering to their own design projects. The assignments also employ *distributed collaborative learning* [Ganoe et al., 2003; Xiao et al., 2008]; the students are asked to work together outside of class using collaborative software over a period of time ranging from several days to several weeks to develop a design analysis or prototype, and a report describing their work.

An example assignment we have used asks student teams to develop a user interface prototyping strategy for a web-based information system. Each team member was asked to review a different case study in which prototyping was employed in order to identify candidate prototyping ideas and approaches, and propose these to the team. The team was then to evaluate, select, and integrate these proposals and compose a joint report.

In this paper, we describe our experiences with case-based distributed collaborative homework assignments in the context of our problem-based usability engineering course. We also describe our experiences developing and employing an online library of case resources and collaborative technology to support these assignments and the other activities in the usability engineering course. We conclude with a summary of lessons learned to date, and some of our plans for upcoming versions of the course.

This research was supported by the National Science Foundation of the United States under awards 0231111 and 0354195 from the Division of Undergraduate Education (DUE), and under award 0735440 from the Advanced Learning Technologies (ALT) program, and by the Edward M. Frymoyer Chair Endowment. During the writing of this paper Carroll was Shaw Visiting Professor in the Department of Information Systems of the National University of Singapore.

II. Learning Activities

We are addressing three types of learning objectives. First, we want students to learn about and practice applying specific usability engineering concepts and techniques (like user interface prototyping). Second, we want students to exercise and develop their collaborative abilities (for example, learn to critically evaluate their team's ideas). Third, we want students to get experience working in teams using distributed collaborative software applications.

We have found that the activities we give students to do need a lot of scaffolding to get them to think more deeply about core course concepts (scenarios, design tradeoffs, etc.). Students, feeling they already know more than they actually do, are more focused on completing the assignment that understanding the underlying concepts of the activity. With respect to usability engineering, this is a well-known challenge: students think that because they are people, they will be able to understand and address the needs of users.

Students also overestimate their knowledge and skills with respect to their collaborative abilities and collaborative software. In general, our students have too simple a view of how to effectively collaborate. Thus, if collaborative process-goals are not explicitly stated, students may simply divide up the work and engage in minimal interactions. Experiencing these interactions are an important objective since they will need to understand users and engage in peer reviews during their careers.

Finally, students are highly experienced with social-networking systems, but rarely have they tried to coordinate activity through such systems. They know how to communicate and interact online, but not necessarily how to coordinate and carryout intellectual collaborative endeavors. Usability engineering rarely takes place in a closed room. Potential users, developers, designers, etc. can be globally distributed, and all play roles in the process.

Pushing students to recognize their knowledge gaps requires reflective activities, modeling, and explicit prompting. Motivating them to develop their abilities is a more difficult task, but holding them accountable for all three learning objectives is a crucial component to providing an authentic usability engineering experience.

A. Case-based Approach to Usability Engineering

Our usability engineering course was designed to be case-based. We created a collection of online case descriptions and made these available to the students. The cases were originally presented via an ASP (Active Server Pages) based Usability Case Studies (UCS) Library website (http://ucs.ist.psu.edu/). There are seven cases, though one is quite incomplete. We choose a variety of domains – mobile banking, telephony (PhoneWriter), online community (TappedIn), online business (Garden.com), nonprofit animal rescue (PAWS), as well as an online version of the virtual science fair prototype case which is also described in the students' textbook [Rosson & Carroll, 2002].

Each of the case studies is a separate hypertext organized, like the path the course follows and like the student semester project requires, by phases of the usability development process. These phases include requirements analysis, activity design, information design, interactions design, documentation, and user testing. Each phase describes how a particular design team developed its scenarios, worked with users, and ultimately validated its design through empirical testing with actual users. For further details on the design of the case studies see [Rosson et al., 2004; Carroll & Rosson, 2005].

Many of the homeworks and in-class activities in our usability-engineering course make use of the case library materials. For example, in the 2009 course, the second homework asked students to study the Tapped-In case and identify at least two conceptual metaphors the designers used to clarify and envision approaches to their requirements. The students were asked to explain how the metaphors contributed to this phase of the design activity. Another homework asked students to identify interaction design issues in the mobile banking case study, and to analyze the underlying tradeoffs for each issue. Students were asked to describe how each issue was resolved, or not resolved, in the actual design work.

Case materials help learners to engage with domain content and to vicariously experience domain practices and situated concepts through a narrative [Carroll & Rosson, 2006]. These cases also serve as models for students of how core concepts can be applied in practice. We found this approach to be attractive to students and effective with respect to learning outcomes [Carroll & Rosson, 2005]. One qualification is that our students have a somewhat narrow conception of what is up-to-date. Thus they sometimes perceive the cases as being less relevant to them since they describe system development projects and practices from the early 2000s. Though a valid criticism, this viewpoint also reflects students' lack of experience and difficulty in generalizing concepts.

B. Project-based Approach to Usability Engineering

Our usability engineering course originated in 1995 at Virginia Tech. Our design concept was to organize the course following the information and activity flow of a scenario-based system development process. We used scenarios as an integrating representational technique, since they emphasize the user's point of view and the importance of describing and supporting work activities as the user sees and experiences them [Carroll, 1995].

Our course starts with user requirements, and scenario-based methods to investigate and describe the users' mental model. The course then progresses to upstream design where user activities are designed by envisioning scenarios, but specific technology, display, information layout, and user interaction decisions are not considered. Following this stage of pure activity design, the scenarios are elaborated with user-interface details. Subsequently, design scenarios are implemented as prototypes, and evaluated with respect to a wide range of usability issues and criteria.

The course was organized around a semester-long system development project. As the course works its way through a curriculum organized by the flows of system development process, student teams define, implement, and test their projects. Roughly, a third of the way through the course they hand in a requirements plan describing how they worked with users to develop their design concept. Two-thirds of the way through the course, they hand in a design document describing how they developed their concept into a prototype. Finally, at the end of the course, students hand in an evaluation document describing how they tested their prototype with users. This course has been successful with computer and information science students. In 2002, we published a textbook based on the course [Rosson & Carroll, 2002]. For details on the course plan see http://ist413.ist.psu.edu/.

During the past two years, the course has changed in two significant ways. First, we have further integrated homework assignments and in-class activities with the semester project. The students take the semester project quite seriously and the grading is weighted to encourage them to do this. However, this makes the homeworks and in-class activities seem like distractions rather than smaller activities intended to help them develop concepts and skills required for the project work. Thus, we reorganized the content of many of the homeworks and in-class activities to more directly support the project work, hoping that this would improve students' engagement with these activities.

The second change we made to the course was to include out-of-class collaboration beyond the semester project. The semester project has always involved out-of-class student collaboration. However, in the 2009 version of the course we included three homeworks that were to be carried out collaboratively over a two-week period. These homeworks were designed to support the semester project-planning that the students were doing, but they were also separately graded deliverables from the project.

C. Taking Collaboration Seriously

When we first started using a collaborative project-based approach to the Usability Engineering course in 1995, we provided general coaching to student groups as to how they should try to collaborate. We suggested they should share all of their ideas, listen to others' views, criticize constructively, try to be sure that everyone did his/her part, and make their group work greater than the sum of the individual parts. In general, the student teams did behave cooperatively, and appeared to enjoy working together both in class and outside class. They frequently became passionate about their projects, and clearly spent much time and effort on this part of the course.

However, there also were recurring problems. Some students contributed little or nothing, and allowed their team members to do all the "joint" work. The remedy for this problem is to weight individual grades according to a student's team contribution, which can be assessed by querying each team member about the other members' contributions. Our students are uneasy with being asked to assess their peers, but this can be mitigated by providing the rationale for this assessment. A complementary approach is for the instructor to observe of group work sessions and try to note who is actively engaged in the joint work. Even just noting attendance at group work sessions can be a meaningful proxy for assessing contribution.

A more subtle problem was that most teams used a management strategy of "divide and conquer". The key joint work they did was to divide the project up into nearly independent subprojects, each of which could be carried out by a single student (i.e., non-collaboratively). At the conclusion of their work they more or less stapled the pieces together and handed the ensemble in as their "collaborative" project.

In the 2006 version of the usability engineering course we designed three distributed collaborative homeworks. Our objective was to provide the students with an opportunity to practice collaboration, and specifically to encourage them to try to use collaborative software. The collaborative homeworks involved analyzing case materials in the online case study library, and creating a collaboratively-authored document using an open source toolkit that supports integrated synchronous and asynchronous interactions BRIDGE (Basic Resources for Integrated Distributed Group Environments) [Ganoe et al., 2003].

There were three collaborative face-to-face activities, each of which had the same basic organization. Each group met in class to plan an approach that would be carried out during the following five days. On the fifth day, the group met again in class to finalize and hand in its results. Each of the activities involved analyzing a case study and trying to apply lessons learned to the team's semester project, and each involved some role-playing. For example, one activity requires members to review a case from the perspective of one of the following roles in a development project: product manager, usability manager, documentation manager, customer/user. Adopting their role's perspective, students were asked to focus on how key issues of documentation design were handled in the case, annotate the case documents, and download them to a collaborative environment.

The aim was for students to see the power of asynchronous collaborative work through such activities. We wanted them to be engaged by the roles and through the roles to experience the inherent conflicts and tradeoffs in decision making in the development process. These activities also provided them with opportunities to function as a thoughtful professional, reflecting on lessons learned in past projects and creatively extending and applying those lessons to new project contexts. In our assignments, the case studies provide a surrogate for prior usability engineering experience that the students generally do not yet have.

These activities did not work as planned. Most of the student teams simply did not carry out the distributed collaboration, but instead tried to cram their work into the two face-to-face meetings we had scheduled for them to coordinate their work. A major factor in this was that we did not explicitly weight collaboration in the grade for this activity. We expected that the opportunity to use collaborative software and engage in collaborative writing would be intrinsically attractive enough to the students that they would at least try these activities. Thus, a lesson we took away from this was that it is important to explicitly assess and grade any collaborative activity that is essential to a course component: providing students with concrete rubrics and expectations for performance beyond the product. This means emphasizing that how they execute their activity as a process is just as important as whether and when they get it done.

D. Distributed Collaborative Homeworks

In the Spring 2009 version of the Usability Engineering course we introduced three new distributed-collaborative homeworks. These were different from the 2006 activities in several respects. They involved far more complex analysis of the case studies, and therefore could not possibly be carried out in class. Each homework was intended to take between two and three weeks to accomplish. Also, we explicitly told the students that we would inspect their collaborative environments and assign grades based on their collaborative processes as well as their outcomes or products. We reclassified these assignments as special homeworks, instead of activities, which called attention to their status as out-of-class work. Reclassifying them as homeworks also made them worth more points toward the final course grade.

Students had to conduct a complex analysis of the case studies in the case studies library. They had to review different phases of design across different cases identifying ideas and techniques in the case studies that could be applied to their team's semester project. Even though the case studies were developed to address other stakeholders and other requirements, the cases could still be utilized as a model of how general course concepts would be applied in real world settings. For this reason we suggested they use the cases creatively, ensuring that their analysis also be informed by their own team's requirements analysis and field work with users and other stakeholders.

In order to ensure equity in participation we tried to structure that activity such that all members needed to make specific contributions. For example, each team member had to recommend user interface design ideas and design rationales to the team based on their individual analysis. They were told to first gather and consider all the different ideas that members had identified, and then prioritize, select and adapt ideas and techniques to their own project. The final result of this particular homework was to envision a user interface design with at least two user interaction scenarios.

This set of collaborative assignments worked better than the 2006 assignments: Every group actually carried out the assignment and produced a collaborative workspace populated with documents. However, the assignment did not work as planned. They were intended to take about three hours, distributed across three weeks. We used a jigsaw design [Slavin, 1980] in which each student carried out distinct but essential individual investigatory activities, the results of which had to be pooled and integrated to reach the specified result. The students were told that we would assess evidence of their collaborative process in the document versions and chat logs in their BRIDGE workspaces.

Their deliverables demonstrated that the teams gathered information, but there was more scattered evidence of synthesis and critical evaluation of the individually gathered information. One out of eight teams clearly integrated concepts from the case studies library with their semester project. Most teams handed in either a summary aggregation of the individual information that was gathered, or a planning statement for how the information would be applied in the design work on the group's semester project. Furthermore students spent little apparent effort identifying which ideas from their individual analyses were the best ideas to carry forward into the group project. Most groups tended to satisfice, to adopt the first reasonable idea identified.

E. Collaboration as a First Class Course Topic

We have found that one of the challenges in making collaboration a course outcome is that many students believe they know how to collaborate. Their understanding of collaboration, however, is "divide and conquer": they see the key to working together as a matter of breaking down the overall project into parts, and are clearly assigning responsibilities that are as independent as possible. They are confident that they can do group work in this fashion, and are therefore impatient about being coached and provided with cognitive scaffolds to enable better collaboration. This is actually a formidable teaching challenge: The students think they have a basic professional skill that they really do not.

In the 2009 version of the course we addressed this directly by introducing an articulated model of collaboration [Borge & White, 2009; Carroll et al., 2008]. We analyze effective collaboration as consisting of effective communication (team member's build on each other's ideas and work to develop a joint understanding), planning (the group's activity is directed by an agenda of goals), productivity (the team stays on track with respect to task goals and ensures work quality), and evaluation-negotiation (different perspectives among members are made visible and addressed, and the group's results are critically assessed). These four facets of collaboration can be embodied in actual roles that students adopt [Borge & White, 2009], in our usability- engineering course we have treated them more abstractly as four essential qualities of the collaborative interaction.

In the 2009 version of the course, we made a systematic effort to teach the four facets of collaboration. In week 2 of the course, student teams videotaped their own interaction as they worked on an in-class activity on requirements change (they were presented with one further requirement for the garden.com design, and asked to analyze the impact of this requirement on the upstream design. In week 3, they were given a brief lecture on the four facets of collaboration and video-based training on the facets (they viewed student team interactions from a prior version of the usability engineering course to see the collaborative facets modeled and then to classify snippets of team behavior.

In the third week of the course, student teams were given their own team interaction videos to review with respect to how they enacted the four facets of collaboration. We felt that a direct self-confrontation would help the students to recognize that their own collaborative skills could indeed be improved. This collaboration thread of instruction during weeks 2-4 of the course was actually fairly lightweight. The lecture we provided was only a few minutes long, and the other activities were interleaved with discussions and other activities focused on various other usability engineering topics.

In week 7 of the course the student teams started the first of the three distributed collaborative homework assignments, as described in II-D above. The instructions for each of these homeworks asked the students to make clear in the writing they did in their collaborative workspaces how they were using the four facets of collaboration in carrying out the homework activity. They were asked to make their collaborative process clear in the chats and other work products they created.

III. TECHNOLOGY SUPPORT

Through the past three years, we implemented our distributed collaborative homeworks using an open source toolkit that supports integrated synchronous and asynchronous interactions (Basic Resources for Integrated Distributed Group Environments, BRIDGE, [Ganoe et al., 2003]). The software supports distributed collaborative team authoring of reports as well as commenting on and construction of new usability cases. Over the history of our usability engineering course, we have explored the integration of these collaborative tools for team work with the content of the UCS Library website. We have found that collaborative software is sometimes too tightly integrated to be effectively used by student teams. Email in particular is problematic in that students rely on it, but already have email clients and accounts they use outside the collaborative suite. We are currently developing an open, web-based collaborative workspace to help students integrate their existing tools and practices with support for collaborative learning.

A. Read-only Usability Case Study (UCS) Library

The usability case study library (http://ucs.ist.psu.edu/) was originally implemented as a ready-only repository using Microsoft's Active Server Pages (ASP) technology. We wanted to exploit the flexibility of hypermedia to allow students to study the cases at various levels of depth, drilling down on demand. This is depicted in Figure 1.

In the figure, a student is investigating the garden.com case study. The student has navigated to "envisionment work" in the information design phase of the case study, using the indented list widget on the extreme left of the window. This displays a

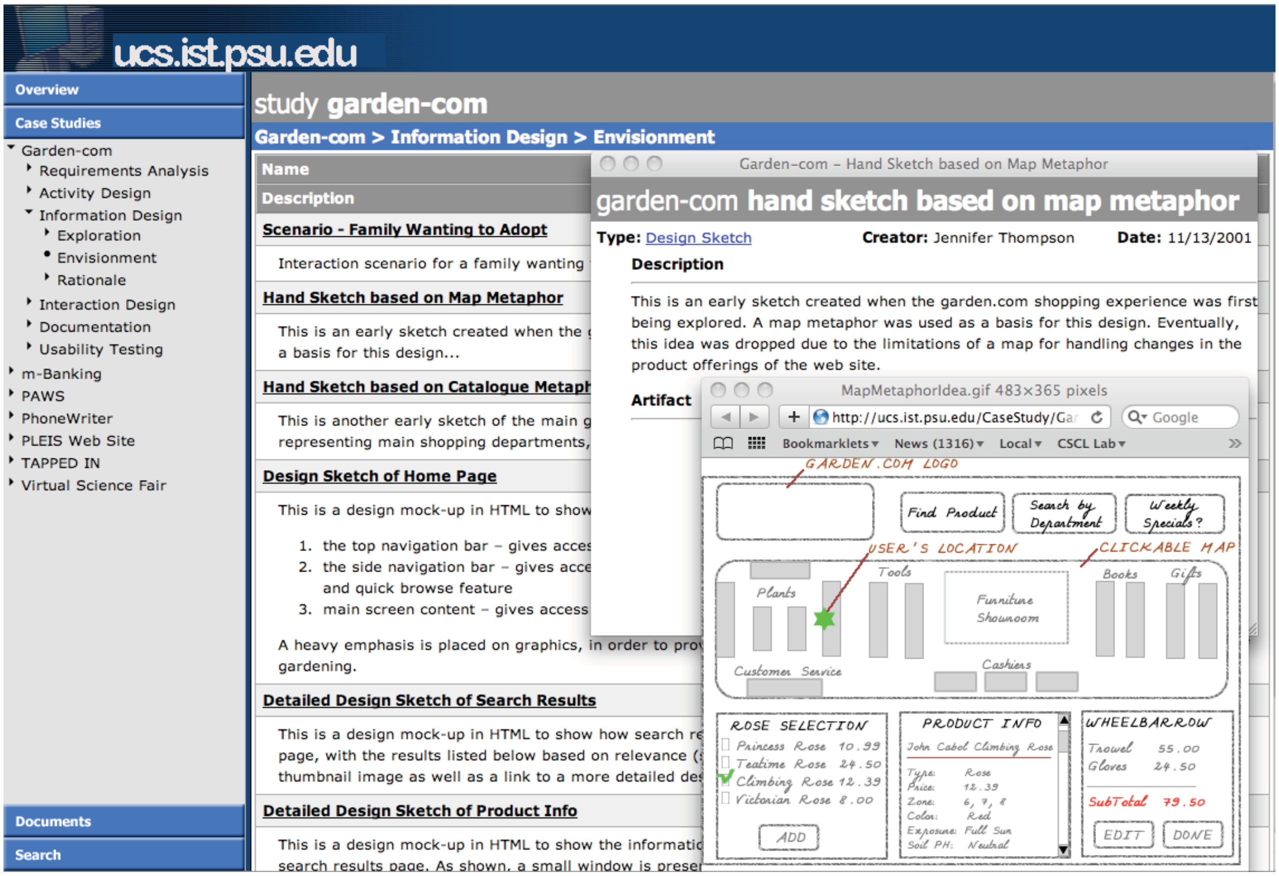

Figure 1. The original, read-only, Usabilty Case Studies (UCS) Library.

series of design artifacts, documents, sketches, notes, and so forth that were produced in the garden.com project during the envisionment part of its information design phase (viewable in Figure 1 in the large right-hand pane of the UCS window). The student is studying a particular design artifact, a hand sketch made by one of the designers illustrating the map metaphor that the designers used during this phase of the design. The description of the hand sketch appears in a pop-up window that displayed on top of the main UCS window. The student has opened the hand sketch, which displays in a pop-up on top of both other open windows.

We have had success with project-based and collaborative case-based assignments using this UCS library [Carroll & Rosson, 2005]. However, through using it we also identified several areas for further development. The original does not support several learning activities that we believed would be useful, and that are highly consistent with the active learning approach we have adopted. Students cannot annotate case-study objects, thus they cannot make notes in the browser as they read case study materials, they cannot highlight or mark them in any way for future reference (including sharing their reactions with fellow group members), and they cannot easily return to materials they have examined before.

Most importantly, students could not create their own cases. Once we started using case-based approaches it seemed obvious to consider having students create a case study analysis of their own semester project. Starting with the 2005 offering of the usability engineering course, we have had the student teams create case study reports of their own projects. Students have reported that this activity helps them to reflect on their own work. However, the original UCS library neither supported multiple user accounts nor convenient means for project teams to create and edit cases. During 2005 and 2006, we jury-rigged functionality to allow students to create cases. As students could not create cases, teachers and practitioners from entities other than Penn State could not either. We know from informally asking colleagues and from a survey we conducted in 2005 that many instructors do use cases in teaching usability engineering (and human-computer interaction). We wanted to make it easier for others to contribute content to the UCS library.

B. *Collaborative Case Builder*

For the 2006 offering of the usability engineering course, we created a collaborative case builder using the BRIDGE toolkit (see III-D for detailed on BRIDGE). This was a partial solution to some of the design challenges of the ASP browser.

The collaborative case building allowed students to download case study content from the UCS into their own BRIDGE workspace where they could collaboratively annotate it, and even directly edit the source content. This functionality allowed student groups to carry out the distributed collaborative activities described in II-C above.

However, a major limitation of this approach was that the case study objects edited in BRIDGE could not be uploaded. Thus, students could work on an editable version of a case study, and could collaborative create their own case study materials as well. But they could not directly save or render this work to the UCS Library website. That step still had to be carried out through a manual, jury-rigged process. Also, potential case authors from outside our university still could add content to the case library on their own.

C. *Editable Usability Case Study (UCS) Library*

During 2007-2008 we developed an editable UCS Library [Jiang et al., in press], addressing the limitations of the original UCS. The new system focuses on allowing users (students and/or educators) to create cases and supporting more authentic learning activities (more usability engineering related practice, more social interaction, more reflection, etc). There are four aspects we especially take into consideration in our design: social interaction, authentic activities in usability engineering, resource accumulation and updates, and communities of practice. For a detailed discussion, see [Jiang et al., in press]. These four perspectives are tightly related and contribute to each other. The functional categories in Table 1 summarize the main functions and design concerns in our UCS redesign, which are affordances for our educational and learning goals.

TABLE I. NEW UCS LIBRARY FUNCATIONS AND REQUIREMENTS

Category	Brief Description	Requirements (Touchstones)
Case schema	Capturing case study activities, procedures and key contents (documents, scenarios, artifacts, etc)	Authenticity
Distributed case authoring	Providing means to allow users to contribute remotely	Resource accumulation and updating
Comments and tagging (Shared)	Providing channels for users to communicate and share information	Community of Practice, Social interaction
Administrative functions	Providing administrative and security functions (authentication and authorization, version control, etc)	Supportive functions

1) Case schema and conceptual framework: In order to capture and support the authenticity of usability-engineering practice, the software follows the phases of the usability process described in II-A. Rosson and Carroll (2002) formulated this case schema for usability engineering case studies, in which the key stages and activities of usability engineering are integrated together into a case structure. This case schema captures the flow of usability-engineering activities and types of documentation corresponding to them. The case schema is represented in the newly designed UCS library similar to the one in the read-only UCS library described in III-A. Students can navigate throughout a case with this schema on the left of the window shown in Figure 2. The team assignments usually cover all stages and activities described in the case schema. For example, when the student team starts to work on their projects, it begins with requirement analysis phase and the students work on detailed activities such as gathering information from user site, interviewing intended users, etc. The structured case schema provides scaffolding for the students to follow the usability engineering processes.

2) Online case authoring: Online case authoring allows students, and other users who have proper access level, to remotely contribute case material to the library through standard web browsers. Our read-only UCS did not provide a convenient authoring method to the wider usability engineering community. This inherently limited the source of usability cases. The addition of proper access controls increases the opportunity for remote contribution of cases to the library. Now, case authors from different institutions and educational sites can contribute to the library.

Users with proper authorization can create new case materials, edit existing content, and delete content objects. During usability engineering activities (interviewing, on-site note taking, videotaping, etc), multimedia data may be collected and uploaded to the system and then referred to with URL links. In order to fully capture and support authentic materials, the UCS system supports digital objects in different media formats, such as video, audio, rich text formats, etc.

The system provides a web user interface for students and instructors to author cases. Thus all the actions needed to create a case are available through a standard web browser. For example, to modify an existing document in a case, someone who has the access can just click edit button on the page which turns the document into editing mode; after editing, one can just click the save button to save it. The UCS Library server will automatically keep a retrievable version as well.

Allowing online case authoring not only brings more case resources, but also provides a means to increase the sense of community [McMillan 1996; Rovai 2002]. Allowing users to create contents is a step toward full participation and engagement within the community, because in our situation, creating a case covers all activities we described in the case schema. In the UCS, we also capture information such as the contributor of content, which gives case authors visibility and credit.

In our usability engineering course, student teams' semester long projects are usually usability engineering projects from real-world. Thus, they essentially create new cases. During the project, students work on each phase and produce reports on their projects. After two semesters, student groups have created 15 cases in the library.

3) Commenting and Tagging: The system allows users to contribute and communicate by commenting on and tagging of

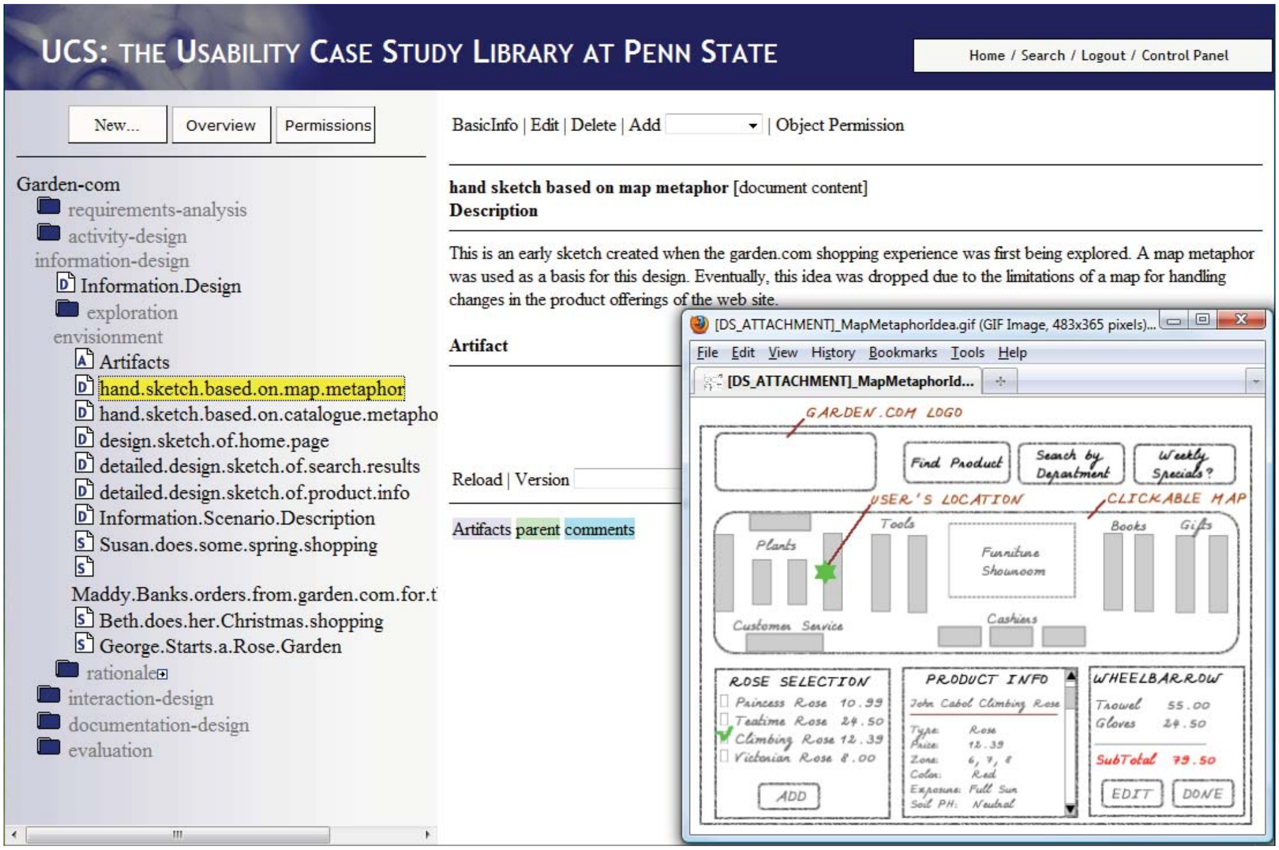

Figure 2. Updated UCS Library with user editing, and commenting features.

case contents. Users who have access to a case can make comments on it, providing their thoughts, ideas, suggestions, criticisms, and so on. Other users can review these comments and add their own. Since comments can be shared across users, the comments can promote discussion and convey information during collaboration.

Tags can help users by providing coded reminders to content or as a way to organize information of interest. In our design, the system will support both public and authorized tags. An example of an authorized tag might be where an instructor would want to set up tags that will only be used by students in her class to find the relevant content for a lesson. Tags will be stored as metadata of the objects. Some services related to tagging is searching on tags, filtering content by tags and displaying all the valid tags in a user's workspace or on the main page for a case. In this way, comments and tags improve the case studies by extending the memory of a user and enabling the user to write down their thoughts, ideas and other reactions on the cases.

4) Administrative functions: Besides functionalities we mentioned above, the system also needed other administrative functions, to make the whole system work smoothly. Those functions are, for example, version control which records histories of all digital objects and from which users can retrieve those histories; authentication and authorization subsystem that secure case contents, etc.

With these basic functions implemented, we deployed the system on an Internet-accessible server. The newly deployed system has been in service for two semesters, spring 2008 and spring 2009, to support usability engineering education. The size of our courses is about 45 to 50. Each week, the instructor selects materials corresponding to the topic of that week from the case collection and asks students read them and reflect on them. Along with other activities and readings, students are asked to review existing cases hosted in the UCS Library and reflect on those cases. In their distributed homework assignments, members of student teams are asked to reflect on case materials and pool ideas contributing to their ongoing projects. For example, in the week we introduce usability evaluation, the students go through the evaluation section in different cases (e.g., Garden.com, Tapped In, Phone Writer, PAWS, m-Banking, Virtual Science Fair), and they are asked to comment on the approaches used in those cases and come up with ideas and approaches of their own when they are in those situations.

The student team semester projects are applications coming from real-world contexts: commercial companies, non-profit organizations, etc, and they are already put into use or on

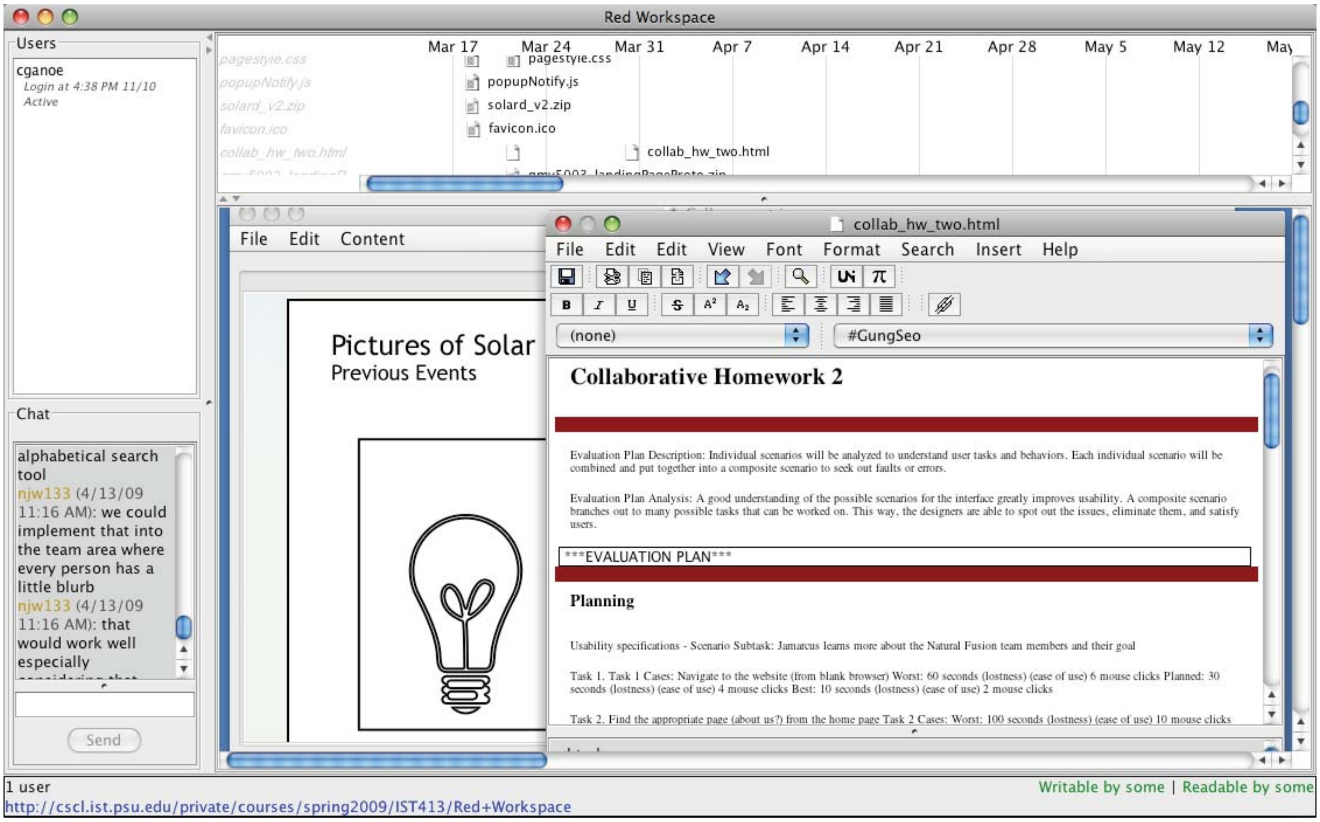

Figure 3. Students develop an evaluation plan in the BRIDGE workspace for one of the collaborative homeworks.

testing. We asked students to work with these organizations and discover possible usability improvements, design/redesign them and evaluate their new designs. The students post their semester-long projects into the UCS Library, so those projects become valuable case resources. In spring 2008, the seven student teams contributed seven cases to the UCS library. In 2009 spring, eight cases were contributed to the library.

D. BRIDGE

In the 2009 version of the usability engineering course, the three distributed collaborative homeworks, described in II-D, were carried out using BRIDGE (Basic Resources for Integrated Distributed Group Environments) [Ganoe et al., 2003], an open source system that supports the kinds of collaborative activities that we are trying to encourage and support among the usability engineering students (Figure 3). Our design for these learning activities requires members of the student teams to be able to individually contribute to the group work. For example, a team might develop a document analyzing how PAWS website designers carried out their activity design, information design and interaction design phases of the non-profit's project. Team member contributions might be made at any time during the 2-3 weeks of the assignment, and their contributions need to be immediately accessible and editable by their fellow team members.

In addition, we wanted the team members to have access to lightweight interaction tools, such as persistent text chat, so that they could exchange ideas, raise issues, and comment on work that was planned or completed. These interactions need to be shared and persist both synchronously, if they happened to be in the workspace at the same time, and asynchronously, if they happened not to be working at the same time.

Finally, we want students to be able to develop the team's final product collaboratively, both synchronously and asynchronously, as possible. In all three of the distributed collaborative homeworks, teams were to create a final document, synthesizing the work that each member had carried out and directing this analysis towards the team's semester project. As mentioned above, we also want the teams to tell us how they had used the four collaborative facets in organizing their work. We left it to the teams to decide exactly how to do this; for example, it could have been done in the chat and/or embedded in the final homework document.

IV. FURTHER WORK

We are currently planning for the Spring 2010 version of our usability engineering course. Our planning is directed at refining our approaches to both learning activities and learning technology. With respect to learning activities, we want to more explicitly articulate the presentation of the collaborative homeworks to help students experience a more sophisticated collaborative interaction. We also want to integrate the collaborative homework activities even more closely with the semester project. With respect to learning technology, we want to create a lightweight, browser-based shared workspace for distributed collaboration.

A. Plans for learning activity design

One development vector in the usability engineering course over the past two years has been greater integration of homework assignments and in-class activities with the group semester project, as described in II-A. We want to further pursue this. First, the students have a huge amount of work to do in this course, and integrating that work under the rubric of the semester project makes it more coherent for them. Second, the semester project is intrinsically motivating to the students; by ensuring that homeworks and in-class activities are more tightly bound with the semester project we may be able to leverage this to increase students' overall motivation.

In the 2009 version of the course, the distributed homeworks were separate assignments that pushed students to apply concepts important to the project, but not directly connected to project deliverables. We want to rectify this in the next iteration. As part of their final semester project, students have to create a case study of their design process; our plan is to design the distributed collaborative homeworks so that they directly contribute to the students' case studies. The distributed homeworks would be used as opportunities for students to reflect and evaluate on their own projects. Students would be expected to incorporate the language of the course to explain their design processes and apply important concepts like trade-off analyses to discuss and defend their design ideas. Thus these homeworks would become artifacts of their design process that would be included as part of their case study and overall semester project.

In order to provide students with more opportunities for collaborative interactions and learning through hands-on activities, our usability engineering course has also evolved from being a lecture-based course with many activities and a collaborative project to being a workshop. We have essentially ceased lecturing as of the 2006 version of the course; the students are involved in interactive activities in every class meeting. Our latest plan would orient this workshop more univocally on the semester project as an integrating workshop activity.

This instructional approach brings with it some inherent difficulties as evaluation of student learning is in many ways dependant on students' in-class discussions. In order for us to be able to evaluate how well students are grasping and applying core usability concepts we need to be able to peer into their thought processes. Rich, collaborative discussions are a useful way to accomplish this type of formative evaluation by drawing out students' ability levels while at the same time providing them with useful feedback. The problem we have encountered thus far is that students are not always comfortable with the risks involved with these sort of discussions: admitting they do not understand, applying concepts incorrectly, making themselves targets for criticism. The challenge for us will be to create a classroom environment where students feel it is okay if they do not have the "correct" answer as long as they can work with others to find it.

B. Plans for learning technology design

Ten years after its initial development [Isenhour et al., 2001; Ganoe et al., 2003], BRIDGE is still a powerful collaborative environment. However, it is too complex for the usability engineering course application. It intimidates the students.

Beyond the specific requirements for distributed collaboration in the usability engineering course, we believe that Internet-based collaboration requires lighter-weight support that more easily integrates with various other Web-based services and information systems. Thus, we have begun to define and develop a new collaborative workspace for use in usability engineering course, and hopefully beyond it.

We think that a core functionality for such a system is the ability to collaboratively author documents. However, we do not think that it is necessary (or perhaps even desirable in some applications) to support character-by-character pushed synchronization, as we did in BRIDGE [Isenhour et al., 2001]. Thus, we are shifting toward asynchronous collaborative writing. Our approach is to allow collaborators to open and work on segments of a shared document. While a document segment is open, it is locked to other users. However, when saved, it becomes available to collaborators, who can open and continue to work on it. As we did in BRIDGE, we will support the coordination of such collaborative writing by maintaining an easily-accessible change history for document segments.

It is vital for students to master a range of collaborative skills in order to successfully accomplish complex collaborative projects. For this reason, we aim to scaffold important team processes such as planning, critical evaluation and reflection. We plan on accomplishing this through instructor modeling, hands on collaborative activities, reflective activities where students evaluate their team's processes to identify the team's collaborative weaknesses, and repeated practice in applying strategies to improve these weaknesses.

A system that supports education and learning should also be able to capture team process at a finer level in order to properly support the full range of collaborative competencies our students display. It needs to support planning, reflection, and evaluation of collaborative tasks and processes in order to allow instructors to help teams: diagnose problems, structure important collaborative processes, and support reflective activities centered on improving these processes. So in the collaborative workspace under design and implementation, besides collaborative writing service, we provide simple and flexible web services to support collaborative team-processes, such as meetings. Teams can create meeting agendas in a workspace and members can contribute by pooling their comments and thoughts as input; the output will be a meeting memo for their future reference. Teams can also create a shared to-do list by which they can track progress of their projects. For critical evaluation on their project design, students can create an idea pool to put their innovational ideas and do pros-and-cons analysis for each idea.

V. CLOSING THOUGHTS

In this paper we discussed our experience with a particular assignment developed for our usability engineering course. We explained the main goals of the assignment and how it connected to the overall goals of the course. We also described the technological tools that could be used to support this activity. We then evaluated the activity after its implementation in order to identify ways that we could improve the activity and make it more useful for our students. Implementation and subsequent evaluation of the activity gave us better insights to our students and to the ways in which the activity was succeeding/failing to meet the original goals we set forth. This process of planning, implementing, evaluating, and refining our educational activity in many ways mirrors the iterative design process used in the development of technological systems. Indeed, it is only through the disciplined use of this design-feedback-redesign process that we can create useful and powerfully rich tools that can advance education and technology and the growing intersection of these two important disciplines.

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Tools for Collaborative Development of Visual Models and Languages

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Abstract—**The paper describes the design and implementation of a set of visual modeling editors. They aim to provide users with easy to use and customizable but yet semantically powerful tools for collaborative modeling in diverse domains of interest. The tools allow the creation, use and evolution of visual models and their underlying languages. The design, software architecture, technical implementation and graphic user interface of visual modeling language tools are discussed. The results of current field trials with the tools are also briefly outlined.**

Keywords-collaborative semantic modeling; ontology; visual models

I. Introduction

Collaborative design is a core element of engineering activity. While in some cases artifacts are designed by an individual engineer [1], design is most often a collective endeavor in which a group of individuals with different backgrounds and interests has to envision, explore, discuss, and evaluate proposals and claims towards the artifact at stake [2][3]. In addition to basic design skills, such as the ability to transfer theoretical knowledge to a particular design problem, to tolerate ambiguity, maintain the big picture, handle uncertainty, and making informed design decisions, collaborative design also requires participants to coordinate and orchestrate the joint effort and to communicate and integrate multiple perspectives effectively [4][3].

To prepare students for the practice of design and engineering in the 21st century, collaborative design exercises and projects became an important element of many study programs. While these efforts appear to have quite positive effects on both learning outcomes and motivation (cp. [4] for an overview of recent findings), research also indicates that collaborative design might suffer, among others, from failures to create a common understanding of and to reflect on the design problem at hand. Typical problems towards that end include an insufficient or inappropriate analysis of the design problem [5][6], design fixation and preoccupation with a particular solution [8][7], as well as tendencies to reduce the complexity of the problem in order to arrive at a solution as soon as possible [7]. In addition it has been argued that from an educational point of view the aim of collaborative design projects is not just to learn how to solve practical problems but also to understand and be able to articulate why a particular solution is supposed to work [10].

To address these challenges various authors have advocated the use of collaborative modeling techniques as a means to foster shared meaning making and reflection in collaborative design, e.g. [1][11][10]. While in recent years various tools and modeling languages have been developed to support collaborative work and learning in general, as well as collaborative design in particular, these tools either make little or no use of recent advances in semantic web technology or they are overly complex to use and hardly in line with the pragmatic requirements of students and professionals alike (cp. [12]).

To answer these challenges the paper describes the design and implementation of a set of visual modeling editors. They aim to provide users with easy to use and customizable but yet semantically powerful tools for collaborative modeling in diverse domains of interest. The described tools are part of the web-based collaborative working and learning Knowledge Practices Environment (KPE) currently under development in the Knowledge-Practice Laboratory project (KP-Lab). The tool set consists of two core components: the Visual Model Editor (VME) and the Visual Modeling Language Editor (VMLE). The Visual Model Editor allows users to create and evolve visual models in the form of two-dimensional graph diagrams such as flow-charts, argument-graphs, organigrams, decision trees, program logic models, conceptual maps, etc. both individually as well as collaboratively. The Visual Modeling Language Editor in addition allows users to create, share and edit the visual modeling languages as such, thereby providing users with the possibility to create their own domain specific ontologies.

This paper focuses on modeling as an inherent epistemic activity relevant to various scenarios in design and engineering education. Based on an outline of the role of modeling for collaborative design and a short review of state-of-the-art tools, we describe high-level requirements for computer-supported collaborative modeling. Against this background a visual modeling languages design, software architecture, tools implementation and graphic user interface are discussed. Finally, we provide a short overview of an initial field trial with the prototype as well as future plans.

The reported work is developed within the Knowledge-Practices Laboratory (KP-Lab) project funded by the EU 6th R&D Framework program.

II. Visual Models and Collaborative Design

Visual Models as means to depict and work with complex knowledge structures have been employed in various domains, including design and engineering, for many years. In its broadest sense visual models are any form of diagram in which concepts or statements are represented as nodes and relations between these concepts are represented as arcs or links. The syntactic and semantic constraints of a visual model are defined by the underlying language. Examples of visual modeling languages proposed for use in design and engineering include concept maps [13], causal maps [1], petri nets, but also argumentation based notations such as IBIS [14] or QOC [15].

Despite the adoption of collaborative modeling techniques and tools in various professional and educational settings, current tools often do not exploit recent advances in semantic web technology nor do they sufficiently address the pragmatic requirements that arise when modeling is not seen as an end in itself but as a means to support collaborative design.

A. Modelling as an Integrated Activity

While in some cases collaborative modeling exercises are aimed to foster the development of particular skills, such as systems thinking [16], collaborative modeling is often embedded in a more encompassing assignment such as a design project. For example, students are asked to develop conceptual models of an actual problem domain [11], to collaboratively articulate and negotiate different stakeholders' perspectives [1], or to explicate and justify the design decisions they made [10]. In all these cases modeling is not an end in itself but a means to support the collaborative design process.

Visual modeling thereby fulfills a variety of often highly intertwined purposes. Even though models are often seen as tool of representation aimed to depict known or assumed properties of a given target system, they can also be understood as "investigative instruments" in that they require an ongoing conversation of participants with the topic at stake, in order to gain better understanding of what is not known yet [17]. As communicative devices visual models can be used to create shared understanding but also to discuss divergent perspectives [1]. Additionally, visual models allow integrating ideas and reference resources throughout the design process, hence providing an evolving record of the design process [11]. Finally, by forcing participants to explicate and document their ideas, visual models provide insightful means for monitoring and assessment [11].

The added value of visual modeling usually arises from a combination of these purposes. While existing tools such as CMap [1], Compendium [2], FreeStyler [3], or the Visual Understanding Environment[4], support the representational and communicative functions quite well, they provide stand alone applications providing hardly any support for other collaborative design activities. Hence, they force users to switch and exchange resources across applications undermining the potential value of visual models as an integrative record. Furthermore, existing tools neither provide sufficient support to track the evolution of the visual models nor to discuss and comment on the elements within the model, making it difficult to orchestrate or monitor the modeling process.

B. Utilization of Visual Modeling Languages

In educational contexts visual modeling languages, such as those mentioned above, are primarily seen as a scaffold to guide the modeling process. While it has been acknowledged that visual modeling languages provide quite powerful tools in that they entail ontological commitments and make some aspects of a domain more salient than others [18][19], the users, including teachers, are usually not in control of the semantics (i.e. the modeling languages) themselves but can select from a set of predefined languages at best. The specification of modeling languages is usually seen as an expert task and priority is given to well-defined "standard" languages, which can be used in a variety of contexts. Consequently tools for the specification of modeling languages usually require substantial background knowledge and enforce explicit and complete specifications, often beyond users' interest [12] and are not attuned to the particular task or problem at hand. Alternatively, tools such as CMap provide only minimal semantics leaving it up to the user to informally agree on the semantics implied by color-coding and selection of various shapes within the models.

Based on the assumption that collaborative modeling requires users to have a common understanding of the concepts and categories used but also acknowledging that ontological commitments are at least partly situated in nature and hence not universally valid [20], both of the current solutions appear quite insufficient. Instead it appears desirable that users can adapt visual modeling languages to their particular needs. Furthermore, limitations of existing modeling languages often only become apparent when being engaged in a concrete modeling exercise. Therefore, it would be preferable to be able to extend or modify the modeling languages on the fly.

III. Pedagogical Scenarios and Design Objectives

To address the challenges outlined above we are currently designing and implementing a set of visual modeling tools which provide users with easy to use and customizable but yet semantically powerful means for collaborative modeling in diverse domains of interest, including design and engineering education.

Pedagogical scenarios to be supported by these tools can take quite different forms. Nevertheless, strong emphasis is put on scenarios that necessitate intensive collaboration on a given topic. Prototypical scenarios include the following:

- Project-based courses where students are asked to work on actual design problems and have to articulate and keep track of the problem space as well as the design decisions they make.
- Inquiry-oriented settings where students are asked to describe and analyze a particular system or phenomenon (e.g. needs assessments, evaluation studies or empirical studies of user behavior).

[1] http://cmap.ihmc.us/
[2] http://compendium.open.ac.uk
[3] http://www.collide.info
[4] http://vue.tufts.edu/

- Topic- or theory-related settings where students are asked to (re-)construct scientific arguments and/or to structure a particular domain of interest (e.g. collaborative literature reviews or state-of-the-art analyses).

Against this background the tools we are currently developing are designed to meet the following goals:

- The creation and use of visual models and their underlying languages should be as integrated as possible. Instead of treating modeling as a separate activity, collaborative modeling should be as tightly integrated into the groups' work processes as possible, allowing for easy access and reference to other resources used. Towards that end, tools for collaborative modeling should be directly integrated into the respective learning and working environment.
- Rather than restricting users to a predefined set of modeling languages, they should be able to modify existing or create new languages whenever needed (e.g. when modeling). To allow for an integrated work on visual models and modeling languages users have to be able to easily move between both levels of abstraction without mixing them up.
- Users should be assisted in developing alternative models and to support the triangulation of different perspectives; these models can be based on the same or different modeling languages.
- Supporting long-term and boundary crossing processes of knowledge creation affords the reuse and evolution of the visual models and languages. Towards this end, users have to be aware of existing models and languages, to understand their specific purposes but also to adapt them to their local circumstances and own ideas.
- Allowing users to create and maintain their own modeling languages also requires powerful metaphors and easy to use tools to overcome the formalization barrier imposed by current tools.
- As concepts and their interrelations often become apparent and crystallize only over a series of consecutive refinements and applications, learners should be supported in the systematic refinement and enrichment of models and their underlying languages. In order to trace the rational of their evolution means for comparing successive versions of models and languages have to be in place. Furthermore, whenever feasible, feedback should be provided to learners regarding possible consequences that a suggested change of the language will have for their model.

IV. KNOWLEDGE PRACTICES ENVIRONMENT AND VISUAL MODELING TOOLS

The Knowledge Practices Environment (KPE) [21] is a web-based collaborative working and learning environment offering various facilities for creating and interacting with knowledge artifacts and knowledge process models. The prevailing user interface paradigm in KPE is based on "shared spaces" – a graph-based view on collections of knowledge objects, which provide real-time and history based awareness to facilitate multi-user collaboration (Fig. 1).

KPE offers various tools for evolving the shared knowledge objects and organizing them visually – wiki, note and sketch editors, annotation and commenting tool, one-to-one and group chats, semantic tagging and semantic search.

A. *KPE Architecture and Technical Implementation*

The Knowledge Practices Environment is a web based distributed software system, which consists of user client, real-time synchronization service, front-end services and data storage (Fig.2).

The client is implemented in Adobe Flex/Flash. When the

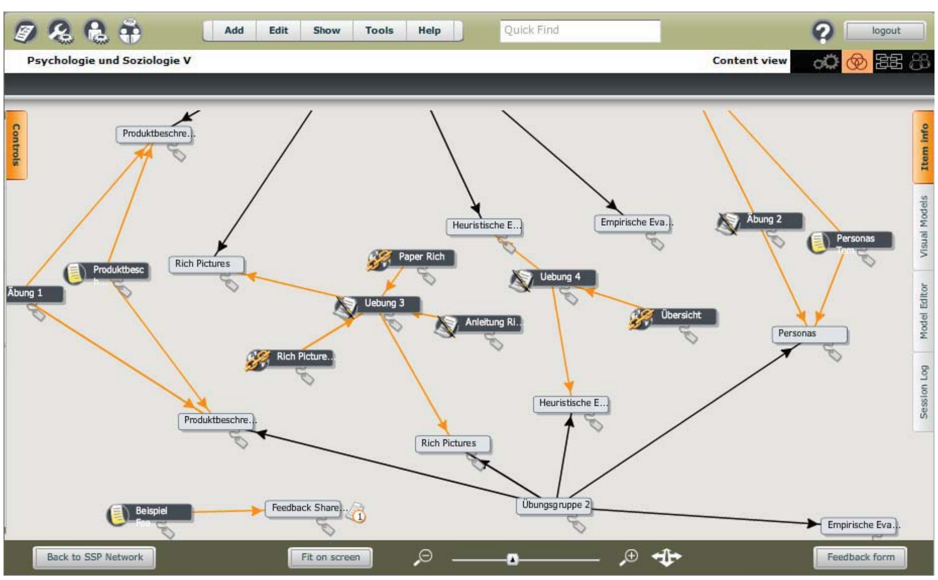

Figure 1. KPE Shared Space.

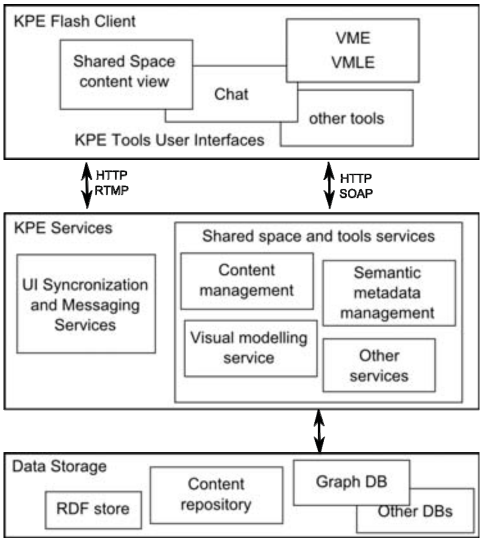

Figure 2. KPE architecture.

user initiates a KPE session, the client is loaded in the web browser and provides a graphical view of the shared space content. The client relies on the front-end services for data manipulation, retrieval and persistence tasks. Most of them are implemented as JAX-WS web services and deployed in Java EE application servers. This architectural decision allows for a truly distributed KPE deployment with different services residing on different servers.

KPE knowledge objects are stored into a heterogeneous database, consisting of RDF store [22] for metadata, Jackrabbit repository [23] for the content (uploaded files, notes, sketches, chat histories), wiki engine and some tool-specific data stores.

A dedicated server, running Adobe Flash Media Server software, is tasked with synchronizing the client's views. All users of a particular shared space can see the changes in the shared space content and layout, inflicted by other users, almost simultaneously.

B. KPE Visual Modeling Tools

The Visual Model Editor (VME) and Visual Modeling Language Editor (VMLE) are KPE tools, whose purpose is to allow users to create visual models and the underlying visual modeling languages as another type of shared artifacts. The direct integration into the KPE allows for an easy transition between modeling and other collaborative activities.

The KPE visual modeling tools support both synchronous and asynchronous collaboration. Users can work on the same model at the same time and changes are propagated in real time to all members of the group or users can work on the same model at different times and when they get back to the system they can retrieve the changes. Moreover visual models can evolve not only based on direct user-inflicted changes but also because the underlying visual modeling languages can also evolve.

Both collaborative developments of visual models as well as the underlying modeling languages are supported. The users

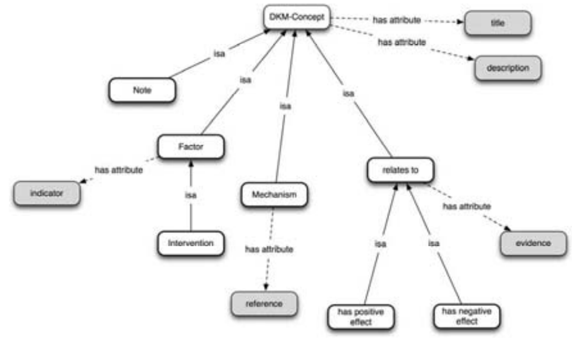

Figure 3. Example of a visual modeling language tree representation.

are free to specify the semantics of the modeling elements used which facilitates the creation of a shared understanding. The tools allow for a controlled evolution of a modeling language preserving consistency with selected existing instances of it.

In KPE the visual modeling languages are modeled as trees, with vertices symbolizing language concepts and attributes and edges representing *is-a* and *has-attribute* relations (Fig. 3).

The KPE users employ the Visual Modeling Language editor to modify the language tree by adding/removing concepts, changing their attributes and defining constrains on the way concepts can be linked together in the visual models.

The visual models are represented as directed multigraphs. Each model is based on a particular modeling language and is constructed from the concepts, defined in this language.

Fig. 4 depicts the user interface of the KPE Visual Model Editor. On the figure, the visual model elements can be identified as white rectangles with arrows between them. The VME allows for references to be created from the model elements to the knowledge objects in the shared space (shown as darker rectangles in the background). The figure also shows a context-chat window, which allows the users, working on the same visual model, to collaborate more effectively.

In order to support the research activities focused on analyzing the evolution of visual models and languages, both VME and VMLE tools keep detailed logs of all changes to the language or model graphs.

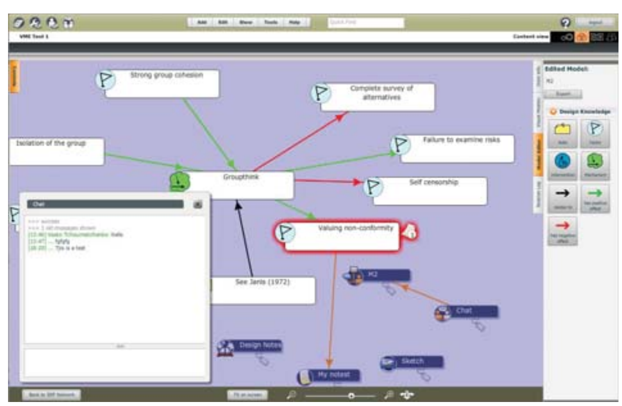

Figure 4. KPE and Visual Model Editor user interface.

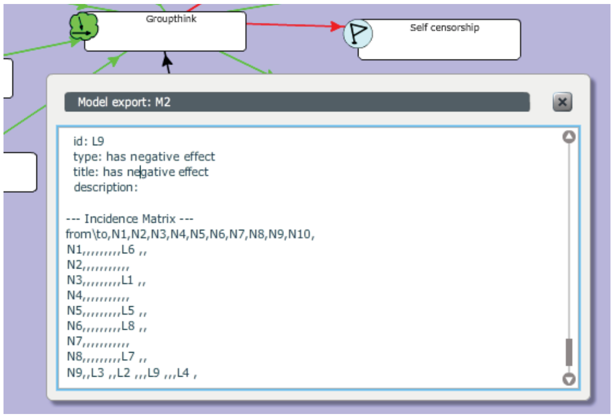

Figure 5. Visual model graph and history log export.

The logs, as well as the models, can be exported in textual format (Fig. 5) for detailed analysis outside the KPE.

The user interface and the presentation logic of the KPE visual modeling tools is implemented as part of the KPE Flash client. A dedicated web service handles the information exchange between the VME/VMLE client components and the models database. The language and model graphs are stored in an embedded graph database, based on Neo4j [24] persistence engine.

V. First Field Trial and Findings

To better understand the appropriation and utilization of the VME in an educational context, the first release of the VME has been tested in two university courses held by the University of Helsinki as well as the University of Applied Sciences Upper Austria in winter-term 2008/09. In the following we provide a brief description of the pedagogical scenario and findings obtained from the field trial at the University of Applied Sciences Upper Austria in the bachelor program "Communication and Knowledge Media".

The field trial was carried out in the context of cornerstone course "eModeration" that is aimed to promote an understanding of design as a form of open-ended inquiry and to engage students in a concrete design activity. Throughout a period of one semester the students are asked to envision, develop, implement and evaluate a solution for a complex design problem in the fields of eCommunication and eModeration. To foster in depth exploration of the design space and to trigger reflection on the proposed solutions, the teams were asked to continuously explicate their evolving understanding of a common design space by means of the VME. Towards this end students were provided with an introduction to principles and methods of needs and problem analysis as well as access to the KPE and the Visual Model Editor. A simple modeling language was introduced to scaffold the needs and problem analysis. Throughout a period of five months 35 students in 10 project teams took part in the field trial. Throughout the semester, the groups met face to face with the instructor alternately every second week.

The main aim of the field trial has been to better understand how students actually make use of the Visual Model Editor and the semantics of the language provided as well as to inform the further development of the VM(L)E. The following observations and findings are based on an exploratory analysis of the models created by the project teams (screenshots had been taken on a weekly basis), the responses to a questionnaire administered to all students at the end of the course, as well as interviews with representatives of four teams and the instructor.

Besides some usability problems, the accompanying research study also shed light on the actual modeling practices. In general the project teams responded quite differently to the modeling assignment, which is reflected for example in the number of additions and modifications made to the models over time as well as their structure. While three groups hardly made any use of the Visual Model Editor or abandoned it after some first tryouts, the other seven groups worked on their models fairly continuously. Among those who used the Visual Model Editor more regularly two groups worked on a single model, while the remaining four groups created 3-7 distinct models.

Even though the "Problem Analysis Language" had been introduced explicitly to the students and scope notes for the different concepts are easily accessible via the Visual Model Editor, the "specified factor", which provides a kind of default concept, was used quite excessively by all teams. Especially those groups who started to work on their models right from the beginning, hardly made any use of the specific concepts provided to depict their design space. This behavior only changed later on after the instructor provided additional suggestions on how the different concepts could be used efficiently. In contrast, two teams that started to work on their models relatively late, made more sophisticated use of the different concepts available right from the beginning. This finding is partly in conflict with the expectation that explicitly defined concepts would scaffold students' elaboration of the design space. It might be that in the early phases of the design process, the effort to explicitly classify ideas according to a predefined scheme does not outweigh the expected benefits or even hinders a brainstorming like collection of ideas. This assessment might change later on when the scope of the project becomes clearer and there is more need to structure and integrate the existing ideas. This interpretation is at least partly supported by the students' reports on how they created and used the models at the different stages of the project.

Some students also mentioned that the predefined modeling languages are too restrictive and that they had difficulties to map their ideas to the concepts provided. Closer examination of the models revealed that several teams had problems to make proper use of the concepts provided e.g. they mixed up resources and actions, and/or to understand the idea of typed nodes e.g. they introduced a concept specified in the Problem Analysis Language as a separate node. On the other hand we also found attempts to proactively introduce additional concepts not provided by the Problem Analysis Language (the Visual Modeling Language Editor has not been available yet). For example on of the teams added a kind of prefix, in this case "problem", to the title of several nodes providing additional categorization. Together with findings from similar courses this underlines the need for a possibility not only to edit the models but also the underlying modeling languages.

The comparison across teams revealed that those who used the Visual Model Editor more intensively often created more than one model in the project's lifetime. While in some cases the creation of multiple models was reportedly due to the fact that the current release of the Visual Model Editor does not allow changing the type of a concept or relationship in a model once it has been created, which make the update of models somewhat tedious, other groups created different models by purpose. One of the interviewee's reported that they had created multiple models in order to be able trace back their understanding at different stages. In another case the participants reported that they produced different models to depict different aspects of their project.

Even though these findings are only preliminary and more in depth analysis of students' modeling practices is needed, it appears that the adoption and utilization of semantically rich visual models might strongly depend on the direct added value for the user. Nevertheless, the assessment of required efforts and expected benefits might change depending on the stage of the project as well as the actual task at hand. Consequently, tools to support collaborative modeling have to be quite flexible in order to accommodate for the changing requirements that arise during the lifecycle of a project. For instance, it requires that users can easily restructure the models they created as well as change the concepts and relations or even introduce new concepts at runtime, which could extend as far as modifying the modeling languages itself. Furthermore, the findings point to the complexity of collaborative modeling as a real world practice that might not only fulfill an epistemic but also a social, pragmatic or even reflective purpose.

VI. Conclusions & Future Work

In this paper we briefly discussed the role of collaborative modeling in the context of design and engineering education and outlined our primary design goals. Against this background we introduced the Visual Model Editor and the Visual Modeling Language Editor as a set of tools aimed to provide users with a flexible and easy to use but still semantically powerful tool for the creation of visual models and their underlying modeling languages. The vision behind this tool is to provide users with the possibility to create their own conceptual tools and thereby to advance pre-existing perspectives while being engaged in a meaningful activity, such as a design project. Based on findings from a first field trial with the Visual Model Editor, it appears that the adoption and utilization of semantically rich conceptual models to a large extend depends on the direct added value for the user, while at the same time modeling fulfils not only epistemic but also social and pragmatic purposes for the user.

An updated version of the Visual Model Editor as well as a first release of the language editing component are currently under development and will provide users with full capability to create and update their own modeling languages in the near future. In parallel, in depth analysis of students' modeling practices and the impact of the modeling activities on the project outcomes are ongoing. These will inform both the further development of the tools as well as respective pedagogical scenarios.

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Embedding Sustainability in Capstone Engineering Design Projects

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Abstract— **The pace of change in education curriculums is growing exponentially due to numerous legislative arrangements and changes. Carbon tax, carbon pollution reduction schemes, emissions trading legislation are paving the way for environmental accountability in engineering industry. Engineering education moves into the twenty first century charged with an environmental agenda due to response to wider changes in society. Educators are regularly modifying curriculum content to embrace sustainability in learning outcomes. However this crosses over between a number of multi-disciplinary, multi-dimensional study areas that include philosophy and ethics. Consequently a major challenge for educators is to encourage engineering students whose primary focus is purely technical to include sustainability viewpoint in their designs. Unlike technical or financial evaluations where measures are either empirical or numerical estimates, sustainability position includes criteria in economic, natural, social, technological and time indicators. For the most part sustainability evaluations are content and competency driven and rely sometimes on rather intangible and proximal criteria. These criteria form the basis of assessment for measuring the sustainability of a design. The purpose of this article is to present various criterion, and indicators available to evaluate sustainability in engineering designs feasibility assessments. The paper presents the application of sustainability design criteria in the context of capstone design projects by way of applying social, economic, ecological, technological and time SEETT framework. These criteria form the basis of sustainability education embedment in engineering capstone design projects. Finally this paper argues the thesis that Sustainability feasibility studies and assessment in capstone engineering design projects are of grave importance for the success of the new frontier.**

Keywords- Engineering eduction model,capstone,new century, indicator, criteria, sustainbility, design, assessment feasibilty.

I. INTRODUCTION

The engineering industry uses vast quantities of natural resources (energy, water, materials and land), and produces products and services. Sustainability is a societal challenge; that also requires the contribution of engineers and technologists. The application of sustainability in engineering is about the implementation of sustainable product and process for the benefit of wider community. Consequently, traditional engineering curriculums were entrenched in the industrial needs of the 19th century; today the new 21st century engineering education model needs to incorporate 21st century principles and ideals including sustainability in the engineering curriculums. However the increasing knowledge needed to practice as a professional engineers and the accelerating rate of change within the discipline suggest that traditional learning models may not address the requirements of learners [1]. Then again the concept of sustainability falls outside the regular numerical subject engineers are classically skilled for. The notion of sustainability education in engineering curriculums is growing at different levels in literature as indicated in TABLE I. Although there are a number of independent efforts to fold environmental issues in existing undergraduate curricula like the Barcelona Declaration Engineering Education in Sustainable Development EESD 2004 which described today's engineers need to acquire new dimensions in ethical, social and cultural issues and systemic vision. No dominant method has emerged as a means of including these concepts. One of the difficulties in adjusting our materials science and engineering (MSE) curricula is the problem of how and what to include in an already full curriculum [2]. Therefore the challenge for the 21st century engineering education model 21EEM is to educate engineers in non-technical issues, which deal with the social subject. This is not to suggest that mere training- equipping engineers with the available analytical tools would be enough to achieve sustainability.

TABLE I. ENGINEERING EDUCATION AND SUSTAINABILITY

Technology to address the challenge.	[3]
Process of change aimed at introducing concepts of sustainable development into activities.	[4]
students' difficulties in differentiating between values and descriptions of phenomena	[5]
sustainable development concepts using cognitive maps	[6]
university engineering courses accreditation requirements	[7]

Sustainability's position in 21EEM would require not just new tools but what's more a new role, being "bilingualism" across disciplines. Therefore, interdisciplinary learning outcomes need to take preference in (21EEM) curriculums to educate the new generation of engineers and technologists. Another vital issue that requires attention in curriculum development is the prima facie of incompatibility between the promotion of an environmental ethic 'sustainability virtues, greener' ideals in education and the political liberal's commitment to 'neutrality' "… the state is not to do anything intended to favor or promote any particular comprehensive doctrine rather than another, or to give greater assistance to those who pursue it…" According to Rawls's political liberalism, which was debated by Derek [8] and Allen [9] arguing that engineering expertise would need to contribute at an early stage in the framing of problems, not just in problem solving; i.e., engineers should have a normative role as well as their more familiar analytical role. The idea of engineering adopting (or returning to) a normative role can be understood by examining the kinds of decisions in which professional engineers as decision makers may be involved with, this presented is as a useful classification of decisions shown in Fig.1.

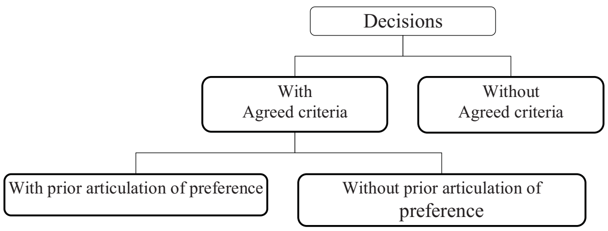

Figure 1: Classification of decisions [10]

The quantitative assessment of engineering design during research, planning and structuring, and implementation and management phases of technological development is important for identifying and prioritizing overall contributions towards sustainability [11]. 14 criteria suggested as vital for the choice of strategies decision makers apply to a given design listed in TABLE II.

TABLE II. DESIGN ALTERNATIVES

Equity	Do those creating the hazard pay for mitigation? Or where inappropriate, is cost equitably distributed among all?
Timing	Will benefits be quickly realized?
Leverage	Will action lead to further risk reduction by others?
Cost	Is there a less expensive way of achieving the same results?
Efficiency	Can the policy be administered efficiently?
Continuity	Will the effects be continuous or short-term?
Compatibility	Is this strategy compatible with others that may be adopted?
Jurisdictional	What authority will have to enact this policy?
Economic	What is the economic impact of this strategy?
Environment	What is the environmental impact of this strategy?
New hazards	Will the strategy itself introduce new risks?
Potential	How much of the risk will the strategy reduce?
Reaction	Are there likely to be adverse political repercussions?
Freedom	Does the strategy deny basic rights?

Adapted from [12, 13]

II. SUSTAINABILITY PHILOSOHOPY

Embedding sustainability education in engineering requires addressing engineers' contribution towards net positive outcome by focusing on minimizing negative impacts on the environment and society. Hasna [14] reported on a taxonomy of sustainability attitude existing within practicing engineers as shown in Fig. 2. In order to respond to these challenges no discussion on sustainability would be complete without mention of the one sustainability philosophy two distinct views, i.e. the pessimism of neo-Malthusians is a sharp contrast with the optimism of cornucopians. Accordingto Malthusians sooner or later population will outgrow natural resources[1]. This is described in the following model;

$$P(t) = P_0 \, e^{rt} \quad (1)$$

The cornucopian school of thought endorses some degree of intractable natural limits to growth and believes through the advancements of technology the world can provide limitless natural resources. However as engineers we view the cornucopian philosophy with a degree of reservations in context of the second law of thermodynamics governs the conversion of energy from one form to another,

$$\partial U = \partial W + \partial Q = \partial W + T\partial S \quad (2)$$

Where dU, the change in the internal energy of a system is equal to the sum of the reversible work done on it dW and the heat irreversibly exchanged with the environment dQ = TdS (which is associated with a change in the entropy of the system). Simplifying the second Law: Law of increasing entropy or unidirectional flow of thermal energy, hence no system is 100% efficient. According Atkisson [15] who reported that we must accelerate our industrial and technological development, or the forces we have already unleashed will wreak even greater havoc on the world for generations to come. We cannot go on, and we cannot stop. We must transform. The natural conclusion here, would be one of comprise between the two viewpoints, therefore contemporary engineering philosophy regarding sustainability is ought to subsume all known definitional variations and takes responsibly of the world's finite natural resources in a manner which will not compromise the ability of future generations. Building on this basis as engineers discussing sustainability in design projects, we have proposed the use of criteria for assessment, in this way we remain true to the physical laws that govern our universe as it is impractical to totally reject it all. Since all of our current practices support Malthusian theory. Hence our role is to achieve a net positive outcome, by putting forward a premise of balance and moderation through the assessment against known criteria.

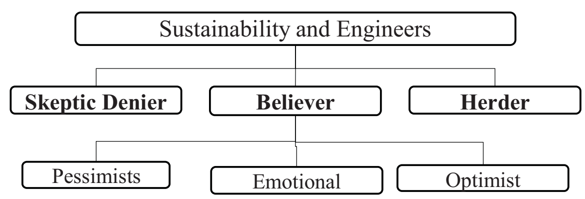

Figure 2: taxonomy of philosophy

Similarly the discussion of how to define sustainability is not new, literature is rich with interpreted meanings and definitions post Bruntland Report [16], whilst these definitions varied linguistically they all share similar nonfigurative, idealistic chic, covering four to six known dimensions[2]. Hence definitional and interpretational meanings directly relate to sustainability assessment. These include converging on protecting the environment and balancing consumption of natural resources.

[1] Where P_0 = Initial Population, r = growth rate, sometimes also called Malthusian Parameter and t = time.

[2] Note that sustainability principles should remain constant over time, whereas the choice of criteria and indicators may change rapidly as knowledge advances.

III. ASSESSMENT TOOLS AND THE ENGINEERING INDUSTRY

Sustainability assessment tools are typically used to estimate achievements of the transformation. Literature is scoured with non-specific, aggregated and ideal indicator sets, proposed by various organizations with interests in sustainability, for example the report on organizations environmental reporting published by [17]. we have reviewed sustainability assessment tools and metrics available for use in the process industries for example; the United Kingdom Institution of Chemical Engineers; Environmental Sustainability Index [18], Ecological footprint [19-22]; World Business Council for Sustainable Development [23] ;United Kingdom Government Strategy indicators [24]; indicators produced in the academic arena [25]. These indicator sets have been identified as having a general focus on reporting towards sustainability. However the literature proposes a bewildering array of tools and processes in sustainability feasibility assessment for engineers. Some are 'graphical integration' tools, aggregating scores of indicators others are 'numerical integration' tools, aggregating indicators. An detailed literature review that covered theoretical and practical approaches to assess sustainability reviewed some assessment tools which may not be widely known amongst engineers but are nevertheless clearly rooted in engineering science cited 55 tools for sustainability assessment framework with an additional 25 software tools [26], Sigh [27] reported on 38 sustainability composite index that included formulation strategy, scaling, normalization, weighting and aggregation methodology. The mentioned tools do not cover industry specific rating schemes and initiatives, that are non comprehensive and non global. Finally it would not be possible to brand any tool as a total environmental solution. According to Spangenberg and Bonniot [28] sustainability per definition is a composite and thus an ambitious policy target.

IV. PRINCIPLES ,CRITERIA AND INDICATORS

In the literature on sustainability much attention is given describing how sustainability criteria should be but little information on the detail, it was found literature lists the criteria to varying degrees by conventional normative criteria. It is stated in Agenda 21 the need for acknowledging the importance of sustainability indicators by both national governments and the international organizations which should be followed by the identification of relevant indicators [29]. The explicit incorporation of sustainability in the decision support process requires assessment of the social, economic and environmental consequences of potential options. This requires the use of sustainability criteria by which to assess these consequences in terms of whether the option is likely to move the system towards or away from sustainability objectives [30]. Sustainability criteria are defined here as the set of factors that may be used to assess which of a range of options, in this case for the development of engineering sustainability criteria which offers the greatest contribution to achieving sustainability objectives. It is helpful, first, to draw distinction between principles, criteria and indicators of sustainability. Principles are normative definitions or goals for sustainability aspire to a universal validity, which can be agreed upon by all. Criteria are the set of factors that may be used to make a judgment about the relative sustainability of a set of options. Indicators measure the past and current values of specific criteria, and may be used to set standards against which future performance can be assessed [30]. Parsons [31] highlighted the usefulness of conceptual models that can explain complex political processes and issues. Sustainability indicator systems encompass a variety of frameworks, dimensions, criteria, indicators, targets and visualization strategies. The variety of processes and measurements can be analyzed from a systems approach and classified by policy purpose and scale. A key component of the system is the interpretation of the term sustainability and how the concept is applied to the particular issue. Chapter 40 of [32] called for the development of indicators for sustainable development at multiple levels. sustainability indicators development are needed in order to provide decision makers with information on sustainable development that is simpler and more readily understood than raw or even analyzed data [33]. In particular, there is a need for highly aggregated and composite indicators, here defined as indices, in which condensed information is assembled. Comparable (SI) indicators and indices with broad international acceptance remains lacking [34].

V. CHARACTERISTICS OF SUSTAINABILITY INDICATORS

Typically sustainability is measured using indicators; Indicators are an essential component of sustainability measurement, but what are indicators ,the word "indicator" has its roots in Latin "indicare" which means "to direct or to point out" [35], however what is a sustainability indicator? The scientific roots of sustainability Indicators lie in the shore of limnology. Sustainability indicators (SI's) science emerged post the United Nations Conference on Environment and Development Agenda 21, Rio Earth summit[36]. The definition of SI's is an important step, as the selection of sustainable solutions is based on these indicators [37]. Many specific definitions in literature exist, they tend to vary little. However there is a distinction between data and Indicator, hence in a general sense, an indicator is a sign. SI's address the crucial issue of sustainability: how can it be measured [38]. In pursuit of influential factors of (SI) for use in feasibility and assessment, it imperative to settle on characteristics of these indicators, to determine what is to be sustained?

TABLE III. CLASSIFICATION OF SUSTAINABILITY INDICATORS

Definition	Author
measurable variable, that provides information sometimes hypothetically linked to another (latent) variable which cannot be observed directly	[39]
variable describes a characteristic of a phenomenon	[40, 41]
parameter, or a value derived from parameters, which points to, provides information about, describes the state of a phenomenon/environment/area, with a significance extending beyond that directly associated with a parameter value, Parameter is a property that is measured or observed	[42]
statistics or measures that relate to a condition, change of quality, or change in state of something valued	[43]
measure that summarizes information relevant to a particular phenomenon, reasonable proxy for a measure	[44, 45]

Hence with respect to indicators for sustainability in engineering, it is therefore crucial to represent a merit-based indicator that provides a snap shot of the design. It is particularly important that the (SI) can be compatible with design criteria hence lending it to be resolved early in the design process. Indicators typically provide key information about a physical, social or economic system [46] provided a comprehensive analysis of various definitions, and demonstrates that an indicator has been defined as "variable", "parameter", "measure", "statistical measure", "a proxy for a measure", and "a subindex", among others. At the concrete level indicators are considered variables. A variable is "an operational representation of attribute (quality, characteristic, property) of a system". Each variable may take different values depending on the specific measurements or observations. Thus, indicators are variables, and data are the actual measurements or observation. TABLE III. presents a summary of the most cited characteristics in literature. Sustainability indicators integrate environmental, social, and economic factors such that the complex cause and- effect relationships between these multiple factors can be more readily investigated [47]. In addition an indicator is a representation of linkages whereby multiple effects can be monitored by a fundamental indicator [48]. Indicators have received increasing attention in the decade, reflecting growing concern by the public and policy makers over environmental trends [49]. However there are two contrast perspectives on indicators:

(I) Indicator-based monitoring tools are frequently applied as effective tools for sustainability assessments [50].
(II) Much of the measurement of indicators has, at the end of the day, largely resulted just in the measurement of indicators [51].

TABLE IV. QUALITY OF SUSTAINABILITY INDICATOR

Scientific quality	Data management
Uncorrelated Independent clear-cut measures what it is supposed to detect measures significant aspect Problem specific Distinguishes between causes and effects Can be reproduced and repeated over time	Easy to quantify Cost effective Data available Comparable across borders and over time Quantifiable Representative Transparent physically relevant Relevant to users User friendly Widely accepted

Spangenberg and Bonniot [28] described proactive indicators cannot focus on symptoms or damages, which only permits an ex-post analysis, but have to concentrate on the underlying trends in order to permit exante measures to be taken on emerging problems therefore, they will usually be response indicators in the (PSR) pressure state response (terminology). Despite the interest in the development and use of indicators the actual operationalisation of indicators to in influence or change, for instance, policy is still in its infancy since there is not enough effort for indicator validation [52]. TABLE IV. lists key attributes for the selection of sustainability indicators, the characteristic are separated into two parts, scientific quality and data management issues, [53]. Therefore, what is the application of these principles, concepts, criteria, factors from engineering design perspective? In this section, we have highlight the central findings in dependent and independent variables, also known as factors, or indicators most prominent sustainability assessment literature to form the empirical foundation in sustainability feasibility assessment in engineering capstone design projects.

A. The Time perspective

Time is the most valued determinant of sustainability; it permits the fuller and more graceful development and deployment of still better techniques to achieve sustainability. Basically the more time is available; the more information will emerge to sustain more robust choices. The time perspectives of most natural resource systems must be at least 250 years, but rather 500-1,000 years is required for any serious sustainability perspective. This can be set against the time perspectives of global climate change/carbon dioxide pollution measures which are planned to fall within the range of 4-500 years. Summarized in TABLE V. a list of four time classifications that can be used to asses an engineering design.

TABLE V. TIME DIMENSION IN SUSTAINABILITY PLANNING

Time Perspective	Years	Description
Instant	2-4	Blink of the eye of the natural system
Short-term	10-30	Fraction of the natural system rotation period
Intermediate	70-120	Is comparable to that of the length of one rotation period
Long-term time	100- 400	Involves more than one to three rotation periods of the natural system

adapted from [54]

B. Sustainability Indicators (SI) Advantages and Pitfalls

Historical research on indicators has been descriptive in nature. This has been useful in the developmental phase of indicator application. Descriptive research in terms of criteria and indicators has been the frameworks [55]. Indicators are different from primary data or statistics in the sense that they provide meaning beyond the attributes directly associated with them and thus providing a bridge between detailed data and interpreted information [56], they have significance beyond the value of the parameter [57]. Thus, indicators provide meaning and concentrated information which otherwise would require an extended detailed amount of information [58]. However, there are limitations of using indicators; one major pitfall is that of subjectivity. Subjectivity enters in two fields: on the selection of the representative indicators and on the evaluation of the indicators results. What Meadows referred to as dependence on a false model and certain scientific and social background and therefore certain degree of subjectivity is inevitable? Other problems include: lack of appropriate data which may result on missing vital information, this further could lead to measuring what is measurable rather what is important [59]; and over aggregation of too many things resulting in an unclear meaning and therefore bad communication and analysis capability. If indicators are not chosen carefully and as systematically as possible they will carry the wrong message resulting in misleading conclusions. Consequently most indicators have not generally been accepted for actual decision-making because of measurement, weighting and indicator selection problems [60].

VI. Principles of Risk Management

Engineering design is subject to multiple, competing tensions. Traditionally, engineering design involves some inherent design risks in the early stages of design that are not always carefully managed, one of main reason is the lack of tools and knowledge to simulate stochastic events (Amir,2004). Four of the main tensions during system or product development have been identified by [61] and are shown Fig.3. According to Australian standard AS/NZS 4360:2004, risk analysis may be undertaken to varying degrees of detail depending upon the risk, the purpose of the analysis, and the information, data and resources available. Analysis may be qualitative, semi-quantitative or quantitative or a combination of these, depending on the circumstances.

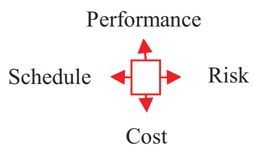

Figure 3: Architecting and design tensions [61]

A comprehensive review of risk management was completed by Pennock and Haimes [62] it was reported that there is a growing body of literature on project risk management composed of a myriad of different approaches and methodologies. In general, there is no one "right" way to conduct project risk management. A comprehensive approach to project risk management can be found in [63], which suggests that project risk management should be a project in of itself. To streamline the subsequent discussion on engineering projects risk and sustainability, this section defines and explains terms and concepts used in this chapter. According to Pennock and Haimes [62] two basic types of risk; technical and programmatic; Technical risk denotes risk in a project will fail to meet its performance criteria. This encompasses the realm of hardware and software failures, requirements shortfalls, and the like. Programmatic risk has two major subcomponents delay in schedule (the project exceeds its projected completion schedule) and cost overrun (the project exceeds its budget or operating costs), this where we propose the interlinks between engineering project technical performance, cost and project's complete sustainability as shown in Fig.5.

. In all cases risk is defined as the probability and severity of adverse effects [64].

$$Risk = \sum_i N_i \times p_i \quad [3] \qquad (3)$$

[3] Where Ni is the consequence (e.g., persons killed, injured) and pi=the probability of occurrence, the two-dimensional components of risk capture its complex nature, but they also make risk a more difficult entity with which to work.

Several systemic methods and approaches are available for identifying and tracking risks. While techniques such as Failure Modes and Effects Analysis FMEA [65] fault trees work well for assessment of pure system failure analysis because there are a finite number of pans. Each part can be examined individually to determine its failure modes and how those failures will affect other parts and the overall effectiveness of the device. However, it has limited effects for assessing sociotechnological systems failure which largely include all engineering projects; hence we recognise need for broad-based, interactive, multifaceted approach to track the projects sustainability risk whilst we identify difficult to capture all of them with a single model. Hierarchical Holographic Modelling HHM is based on the premise that no real-life system can be adequately represented by a single model, to do so would be to present only one dimension of the system[66, 67]. Hence we propose investigating the critical and important facets that make up a constitute sustainability system criteria, this is proposed through a comprehensive qualitative assessment to establish topics or set of subtopics for engineers to refer to similar to sustainability assessment criteria.

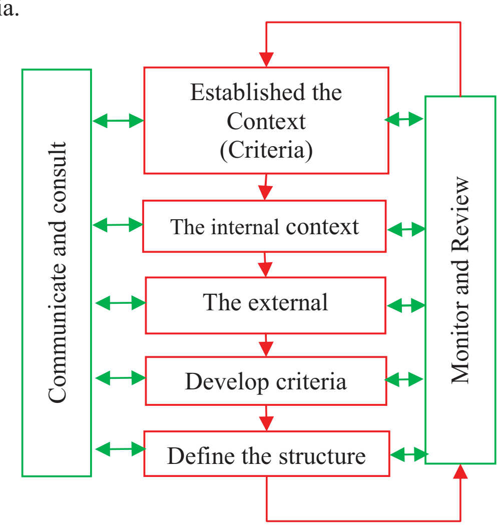

Figure 4: portions of risk management process[68]

VII. SEETT Methodology

SEETT is a simplified sustainability framework in which it combines social, economic, ecological, technological and time; it addresses complex relationships between these dimensions. The SEETT framework is a conceptual model that integrates sustainability boundaries between goals and indicators. The boundaries of sustainability indicators found are illustrated in Fig.6. It can not only help with the selection of indicators, but show what is not being selected and what might be important in the future [57, 69].Without a framework, indicators can easily proliferate and be little more than a conglomeration of disparate data. There are already numerous evaluation frameworks, however, they are industry specific and do not offer versatility for users to utilize a universal sequence. It is crucial in fact to separate indicators of un-sustainability to gain a common understanding, about what is to be measured. because engineering student need to realize that sustainability is related to risk assessment of a project since one of the core concepts of sustainability is good environmental stewardship [70] for the engineer, technologists and designer, creating sustainable systems involves making engineering and design decisions based on multiple dimensions: technology, ecology, economics, and socio-cultural, including ethics [71].

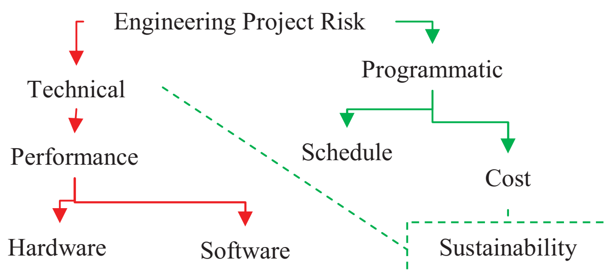

Figure 5: Engineering projects risk identification.

There are already numerous evaluation frameworks in existence, however, they are either industry specific or do not offer versatility for users to utilize a universal sequence. It is crucial in fact to separate indicators of un-sustainability to gain a common understanding, about what is to be measured. because engineering student need to realize that sustainability is related to risk assessment of a project since one of the core concepts of sustainability is good environmental stewardship [70] for the engineer, technologists and designer, creating sustainable systems involves making engineering and design decisions based on multiple dimensions: technology, ecology, economics, and socio-cultural, including ethics [71].

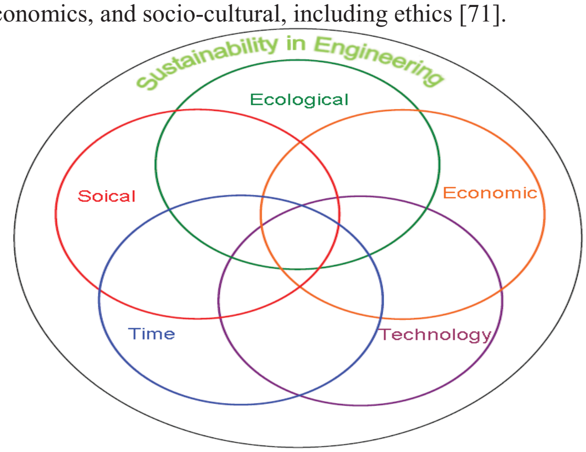

Figure 6: SEETT (social, economic, ecological, technological and time)

The general methodological framework proposed in this paper is an attempt to contribute towards standardization of the indicators of sustainable development for industry. The standardized indicators have many advantages for bench marking. The reviewed indicators suggested a common reoccurring theme, demonstrating a similar array of indicators, with different terminology, goals, scopes and end use, the indicators were streamlined into six distinct categories, social economic, ecological, technology, and time but not implicitly displayed expressed. A summary list of criteria from a large body of literature was selected from the most recurring, is listed in TABLE VI. In addition institutional vastly discussed and recommended as a separate theme, and other times it was integrated within social. Therefore in the assessment we are looking for;

(i) Measures of relative dependence of the economy on non-renewable sources of energy and materials,
(ii) Measures of the productivity of energy and materials consumed by the economic system and
(iii) Measures of dissipative loss, especially of toxic and hazardous substances.

VIII. Discussion

Risky technological projects might affect the well-being of people. Technological risks directly give rise to ethical issues [72]. The criterion provides answer to the students many questions for example when is it justified to impose dangers on others? And how should we judge whether a risk is morally acceptable or not? Engineers define risk as a function of probabilities and unwanted consequences. Examples of unwanted consequences are the number of deaths or injuries, or the degree of pollution. Policy-makers use cost-benefit analysis to weigh the possible advantages of a technology against its possible disadvantages. Many social scientists who work in the field of risk analysis argue that cost-benefit analysis and the definition of risk as a function of probabilities and unwanted consequences are not sufficient to determine whether a risk is acceptable or not. Many social scientists claim that since all risk judgments, also those of experts, include values, all risk judgments are subjective and socially construed. objectivity equates with what is 'out there' and with what is quantitative[73], whereas all of the following notions are grouped under the label 'subjective': 'social construction', 'values', 'assumption-ladenness', 'judgment', 'intuitions', 'subjective assessment', 'qualitative', 'emotional', 'contextual'. Some of these notions are by definition subjective or at least not objective, i.e., subjective assessment and social construction. However, the other notions are not necessarily subjective.

Values, judgments, intuitions, qualitative, emotional and contextual are also not necessarily subjective notions. Judgment, intuition and emotion are 'subjective' in the sense that they are bound to persons who have them, but this holds for all our cognitive abilities. The question is whether these abilities can help us assess what is really there? This is a philosophically controversial issue; it is far from philosophically obvious whether emotions, judgments and values are subjective projections or rather, if they are forms of objective discernment. According to most contemporary moral philosophers, moral values are not arbitrary or subjective. Whilst sustainability indicators act as a critical monitoring tool vital to the sustainable management of societal and natural resource and one of the most used tools for communicating information to decision makers indicates that there has been no agreement or consensus on a common set of scientific and management criteria for evaluating indicators from several points of view i.e. reliability of supporting data, scientific rigor of definitions of indicators, validity of underlying assumptions and concepts, relevance of positive or negative trends for sustainability. If decision makers and engineers are to continue basing their decisions on the information thus provided, we must therefore ensure that such indicators be not only scientifically valid but also policy relevant. In order to obtain a scientific validity of the aggregated indicators a scientifically sound methodology is required on the elaboration of indicators, data gathering, data processing, measurability. Integrating, environmental, social, economic, technological and time Indicators of sustainability must be agreed on, transparent, and sufficiently broad criteria, subject to rigorous scientific assessment to be widely accepted. This "wide-angle" is even more critical as it is necessary to discuss the complex interlinkages between the biophysical, social, economic, technological, institutional aspects are appropriately taken into account. Since existing aggregated indicators are often criticized for their shortcomings in this respect. "…everything is an indicator of something but nothing is an indicator of everything…"[74]. This view suggests that a 'sustainability index' is impossible to design. They also suggest that indicators should be selected 'to maximize unique, relevant information and to minimize redundant information'. This presumes that we understand what is relevant and what is not. One thing that scientists have learned over the years is that our knowledge is very limited, otherwise how could we have had an acid rain issue or an ozone depletion issue? But Cairns et al [74] also refer to the consequences of two forms of uncertainty: (1) false negative (FN) signals and (2) false positive (FP) signals. FN signals provide no warning of potential harm when it is bound to occur and FP signals warn of potential harm when none exists. They conclude that multiple lines of evidence (redundancy) are more likely to protect against unpleasant surprises. So rather than minimizing redundancy, the 'sustainability index' should use many indicators (hoping that some of the information obtained will be redundant). Although it is recognized that no single process can describe a universal engineering approach to (SI) however this is a roadmap reflections on the indicator design process that yielded the following key points: Lyytimaki [75] described building a sustainability indicator collection without a concrete, well planned conceptual framework may provide a cheap and quick solution that is sufficient for some situations. The drawback is that the organizing structure and relations between issues and indicators remain obscure and elusive. This kind of ad hoc framework may also easily neglect important issues and highlight wrong issues.

IX. CONCLUSION

This generation is charged with an unprecedented responsibility underpins all human activity; sustainability in engineering education is often referred to as the new frontier due to the numerous legislative changes which are in the pipeline, overlaid with challenges for engineering educators. Therefore the need to prepare engineers to identify and analyse energy usage, areas where reductions can be made through sustainability assessment is paramount. In addition using sustainability criteria in design curriculums can engage engineers to contribute to sustainable development through designing, developing and implementing solutions that are socially acceptable. Given that there is no universal framework or uniform methodology to apply the vision in capstone engineering design projects. In this paper, we propose SEETT a path for integrating environmental and sustainability concepts within the framework of existing curricula conducive towards sustainability in engineering capstone design projects. The presented list of SEETT criteria is a first attempt, intended for achieving a common-metric to address limitations sustainability assessment in class rooms. From this point of view we argue that it would be uncomfortable for students in engineering classes to assess sustainability or work in cohesion if we do not have a similar contextual engagement.

RECOMMENDATION

The global engineering educator's community recognizes the critical need to develop and practice sustainable techniques in design curriculums; one way of achieving this framework is by developing cases study banks to translate experiences of using indicator. The table below collates sustainability criteria SEETT, (social, economic, ecological, technological and time). One way of increasing criteria confidence and value usefulness to potential users is through case studies validation checks which can also assist improving the indicators to meet a satisfactory degree of 'accuracy', and 'credibility'.

TABLE VI. SEETT CRITERIA

Social Assessment Criterion
Aesthetics appearance and nuisance
Social Cohesion Dislocation and Culture
relocation of people
Knowledge or skill enhancement
Education & Training
Recreational value
Provisions for underprivileged
Shelter Impacts upon indigenous, or minority ethnic groups
Heritage perseveration
Improving of living standards
Employment opportunity
Occupational hazards (e.g. falls, fires, explosions, operation of machinery)
Perceived Risk Loss of livelihoods
Increased risk of natural hazards (e.g. floods, slips)
Exposure to physically hazardous wastes (e.g. 'sharps')
Nutritional value provided
Increases Food supply
Mortality reduction-quality of life
Impact upon cultural, historical or religious sites or values
Accessibility increases competition, Ethnic Diversity
Incorporation of women Impacts upon women
Impacts upon the poor
Economic democracy
Avoids Illnesses
Stress at work
Spirituality , Promotes justice , Security
Transparency Participation
Sanitation, Communal violence
Credit and investment
Democracy Transparency
Quality of Life , Equity, Ethics
Institutional , Illness & Disease
Accident & Injury, Health & Wellness

Ecological Assessment Criterion
Virgin source of materials
Recycled materials
Origin of materials
Greenhouse gas
Manufacturing waste

Packaging Existence of rate/ endangered species Disturbance of existing fauna Noise pollution Water Run off Monitoring environmental impact Smog creation Ozone Depletion Climate regulation Biodiversity reduction Design objective Non recyclable waste Energy efficient Use of fossil fuels for energy needs (i.e. CO 2 emissions) Energy consumption Acid rain precursors Global Warming Carbon monoxide (CO), nitrogen oxides (NO_X), sulphur dioxide (SO_2) Heavy metals (e.g. lead, mercury, chromium, zinc) Water quality Destruction of carbon sinks (e.g. forests) Release of other greenhouse gases Release of CFCs ploychlorinated dibenzo(p)dioxins (PCDD) polychlorinated dibenzofurans (PCDF) polynuclear aromatic hydrocarbons (PAH)polychlorinated bipenyls (PCB) hazardous chemicals dioxins1, furans2, PAH3, PCB4, nitroaromatics, hazardous chemicals pesticides, herbicides, asbestos

Economic Assessment Criterion
costs Operation costs (raw material, labour, upgrades) Closure cost (i.e. site restoration, legal liability costs Construction costs (i.e. land, equipment, infrastructure) Maintenance costs (new parts, down time, labour) Competition effects Stability Resource depletion Ecosystem productivity loss **Employment** GDP Deficit; and capital flow; debt Stability in prices; debt Social factor productivity **Raw material** Waste hazards Solid Wastes or Hazardous Products Liquid Wastes or Hazardous Products Gaseous Wastes or Hazardous Products Capital, Labour, Fixed Viability CBA ,LCA , NPV Energy resources , Fossil fuels Useful product lifetime Product disposition cost Clean technologies; adequate waste management reduction of all forms of pollution Resource depletion, Recycling revenue Consumption of goods and services Institutional Ethics

Technology Assessment Criterion
Source of the technology Indigenous to the area or Imported Relatively new/unproven System performance Decommissioning of technology Type of technology Existing Processing/manufacturing Based on the use of natural resources Flexibility and adaptability Business interruption Customer warranty cost Ecosystem productivity loss Loss of goodwill due to customer concerns Residual consequences Disruptive to the environment Resource depletion Ecosystem productivity loss

Design iterations Resource Scarce Renewable /non Hazardous materials used Product & packaging mass Power use during operation Biodiversity reduction Needs and basic rights Leisure time and enjoyment of family life Social assistance and culture Sate of right and public safety Identity and self-esteem Health and social security Corruption, participation of civil society cooperation , and agreement; solidarity and altruism Creativity governance expansion of civil liberties

Time Assessment Criterion
Does the project, product or process have a lifecycle? What is the deign life of the project, product or process. Does the proposed project, product or process contribute towards reducing non-sustainable practices to zero over the project time frame? What is the expected usability for the project, product or process? If outcomes cannot be accurately foreseen, is your planning based on risk reduction and the precautionary principle?

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Project-Based Collaborative Learning of Electrical Engineering Master Students

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Abstract—**The paper outlines a project-based collaborative learning methodology developed for graduate courses on Electrical Drives and Power Electronics in Tallinn University of Technology. An underlying principle of the described environment is the coursework arrangement directed to designing optimal application-specific drives with power electronic converters based on the active learning approach. The role of advanced computer-aided design tools is also identified and shown. To illustrate the effectiveness of this method, the industry-relevant course projects performed in the curriculum are presented in detail. An important result found is that all students acquired knowledge and skills to design more complex and sophisticated electromechanical systems.**

Keywords-active learning; collaborative learning; project-based learning; electrical drive; power electronics

I. INTRODUCTION

As shown in [1], [2], [3], the traditional methods of teaching encourage a *surface approach* to learning, where students try to follow the routine solution procedures and match patterns rather than follow a *deep approach* where students develop a conceptual understanding of how the study system operates. Focus in the surface approach is on the ability to repeat what has been read without necessarily understanding it. Students' learning habits concentrating almost exclusively on exams, lead eventually to an overload, which in turn tends to result in a low level of knowledge. This effect is certainly causing students' stress and missing motivation. Therefore, traditional teaching appears to be ineffective in generating student enthusiasm and passion for learning. In this case, students may not be able to achieve the required goals to the full, or may be slow to reach their full creative talent and engineering potential.

Meanwhile, engineering companies require an aptitude for collaborative work, team and task management, concept synthesis, and decision-making from the graduates, thus promoting creation of a new environment for learning, which would provide all of these job-related skills. The main objectives are to provide high-quality teaching in terms of content in order to motivate students to learn additional skills not directly related to a speciality, however, considered very valuable in the professional working environment.

Contemporary changes in the business area, responses of companies to these changes and the available technologies pose a number of challenges to the present and future engineers, as well as to the educational institutions, including

- collaborative work in the cross-functional, multidisciplinary, multinational, geographically dispersed teams
- creative work with a global customer base through developing communication skills with regular application, transfer and improvement of engineering knowledge

The Bologna meeting of 1999 set the convergence of all the national university programs of the European partners on a path towards a common frame. The main recommendations of that meeting concern the equivalent degrees implementable in more specific subjects and areas of shorter duration. A practical approach to teaching becomes more important in technological degrees, where students graduate and search for jobs in fast evolving companies.

As learning is a cognitive process, knowledge has to be constructed in the mind of the learner, in his/her efforts and activities. Learners can develop complex reasoning skills effectively when actively engaged in the material they are studying. They build meaning when reading, writing and discussing. Learning is aided by conversation that seeks to describe and clarify the ideas of the learners. Clarifying of understanding requires that students be provided opportunities to articulate their ideas, to test those ideas through experimentation and discussion, and to consider the connections between them.

From this viewpoint, an *active learning* strategy involving project-based learning and collaborative learning seems prospective [4], [5], [6].

Project-based learning, called also *learning by doing*, is a student-centered strategy that fosters initiative and focuses a student on authentic real-world open projects that can increase motivation for the majority of students and enhance their education [7], [8], [9], [10], [11], [12]. One aim of this approach is to organize the courses so that the students would be motivated to study.

Collaborative learning, called also *team-based learning*, is an educational method where students work in small self-directed teams to define, carry out and reflect upon a research task, which can often be a real-life problem [13], [14], [15],

[16], [17], [18]. The tutor acts here as a facilitator and resource person who they can meet for advice or guidance. This approach emphasizes cooperation and creating team learning and developing culture and makes it possible to include and use various scientific perspectives and methods of learning, research and development in operation and action.

To develop a new curriculum in Tallinn University of Technology, an experience of the partner institutions was used. Particular attention was paid to the 25-year experience of project-organized undergraduate education based on a unique pedagogic model of teaching gained at Aalborg University. In this method, a large part of semester teaching and student work revolves around the complex real-life problems or issues that the students consider and try to resolve while working together in groups [3]. Similarly, the curriculum structure proposed in [7] consists of eight courses: four theoretical courses and four project-based courses (including a compulsory master's thesis). In the project-based courses, the students working together in groups develop multidisciplinary systems, which become progressively more complex. An important result is that all students have developed effective systems, while considering that the results are worth the effort invested.

The following sections of the paper analyze the benefits and restrictions of the active project-based collaborative learning techniques based on their implementation experience in the master study program of Tallinn University of Technology. The description of each method is followed by the recommendations concerning possible ways of their use in electrical engineering education.

II. Design Objectives

One example of active learning is the system built by the authors to study the disciplines included in the electrical engineering curriculum. The Advanced Course of Electrical Drives (AAV0040) and the Advanced Course of Power Electronics (AAV0050) are the master study optional courses provided in the Faculty Handbook. Course duration is 16 weeks, consisting of 3 contact hours per week and at least three hours of weekly independent work.

An electric drive is an electromechanical system that provides controlled inductive conversion of electrical energy into mechanical motion. It consists of mechanical transmission, an electric motor, an electronic power converter, and an informational controller. The power of supply lines is transformed into motor supply energy by the power electronic converter. Then, the motor converts it into electromagnetic energy, which in turn is transmuted into a shaft's mechanical energy. The controller forms the input references using information of the set-points, outputs, and disturbances. The engineering goal is to build an effective system using the components proposed by many world companies. Effective assembling of electric drives can solve the problems owing to rather complicated algorithms. Here, the mechanical, electrical, electronic, and power engineering problems are encountered in close integration.

The procedures of a motor drive and power electronic converter design involve a number of complex problems. Some of them are

- timing calculation and the mechanism travel diagram construction
- computation of mechanical forces and the torque/power patterns synthesis
- gear and motor dimensioning and selection
- the optimum motor-gear set choice and checking
- power electronic converter dimensioning and selection or design of the new one
- building the motor drive and power converter wiring diagrams
- development of controllers for the multi-loop control and adjustment
- the process simulation along with the analysis of the steady-state diagrams and transients
- economic considerations and efficiency evaluation of the project
- report generation, presentation and defense of the obtained results

Today, two ways of the drive development are used in the designers' community [19].

The first of them starts from the selection of a manufacturer; further, the manufacturer design technology and recommendations are used. For computation and equipment selection, the leading world companies have developed their specific technologies. Examples are the guidelines and software of Siemens, Omron, Sew Eurodrive, Maxon Motors, Mitsubishi Electric, etc. Such an approach is common for the majority of firms that carry out project design and have rich experience in acceptance of the decisions based on extensive computer data sources, making up numerous catalogue archives and "absorbing" their contents and structures.

The main drawback of the approach is the restriction of the design technology by the vendor company selected as a preferable manufacturer. Data limitations deprive a designer of an optimum way in the project. It is especially sensitive in the first project stage when the most responsible decisions are taken. Different manufacturers have worked out hundreds of databases and soft tools that provide most of the stages described above. All of these data sheets use different languages and operation systems. They have multiple structures, data types, data fields, keys, names, and inter-sheet connections. Not all required data are published; occasionally the knowhow of manufacturers may be concealed from the user. It is frequent practice that the provided information carries an advertising style, unnecessary for design purposes. Some data are published in the Internet; other information is accessible through printed materials and journals.

The second approach was proposed first in [20], [21] and then developed by further research into a computer-aided design system. As different from the companies, which manufacture and propagate their production, the proposed approach is addressed to the overall equipment selection, tuning, and optimization process independent of company

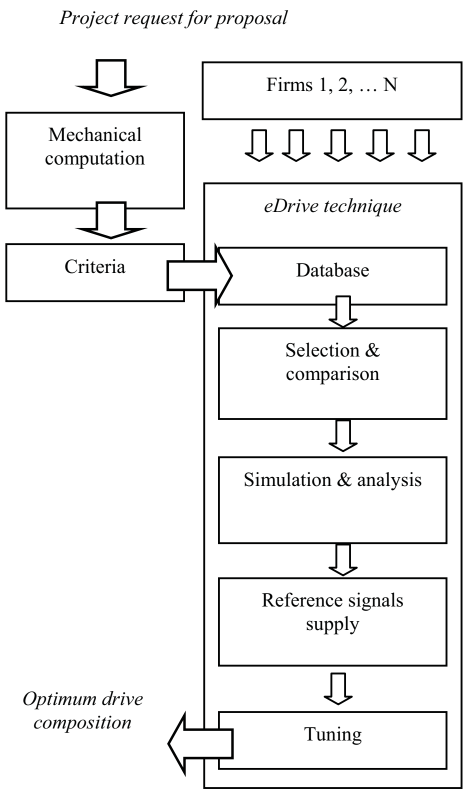

Figure 1. Project mastering structure

interests (Fig. 1). Using a search technique, the system transfers multiple data from a variety of databases into the uniform *eDrive* database (Fig. 2) with the specific data management system, which provides the search and updating of the data using the open-access corporative databases. The design process starts from the load computation using the project developers' own experience and methods. Further, a designer selects a group of gear types from different companies using the results of the load calculation. Through these gears, the forces and mechanism speed found before are converted to the equivalent values on the motor shaft. Then, the particular motor type that matches each gear type is to be selected based

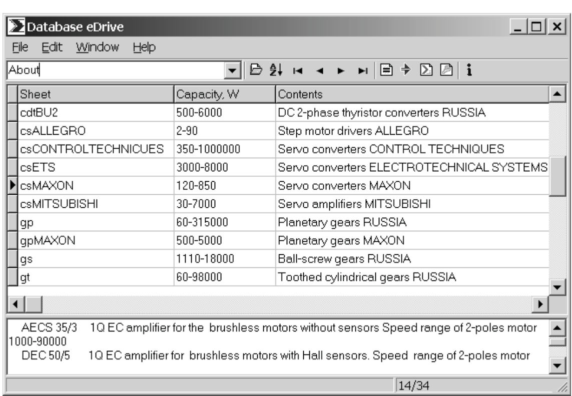

Figure 2. Database window

on the converted forces and speed. Thus, a set of possible drive variants is generated. Once the equipment framework is found, the new problem appears – which of the suitable motor-gear combinations is optimum? To find a solution, a designer can form appropriate criteria and sort them. It may be a criterion of maximum accuracy or speed, minimum weight, power, or inertia, highest rigidity, etc. Thus, the whole scale of the electromechanical and electronic properties is collected, from which the choice is done based on judgments about preferences of that or another criterion. Then, simulation of the open-loop system is done using the standard or the original simulation software. On the next stage, the power electronic converter equipped with a control system, which includes some regulators and sensors is designed or selected. Their transfer functions, gains, factors, and time constants are calculated to meet the standard settings. Then, the closed-loop system testing is carried out on the model and its optimization is executed, if necessary. This approach is more suitable for the educational targets thanks to its universality.

The learning outcomes for the multiple subjects in the master training program were listed by the researchers and industry agents. Senior engineers from various industries were contacted for their ideas regarding suitable industry relevant projects for the master students. Following a series of industry meetings and feedbacks, suitable topics were specified. The modules were designed, built and tested by the researchers. Then the specification sheets were handed to the students at course start. The projects are designed in a modular fashion, so that any independent module can be completed during the course that the student has enrolled in. The independent modules are assessed by the instructors teaching the course.

The master students are expected to design, build and test various modules as specified in the projects within a period of some months. In some projects, the students work individually, in other they are joined in groups of four while working on the project. They have to use the theoretical knowledge of Electrical Drives and Power Electronics as well and Computing Engineering, Mechanics, Automatics, etc. gained during their bachelor and master study. On completion of the project, students' learning experience and learning outcomes will be used to prepare their master's theses. The students' practical skills are assessed while working on the project, and their theoretical knowledge is graded on a written exam after the project completion.

III. PROJECT-BASED LEARNING

The main aims of an educational project are

- to set interactions and collaborations between teachers, students and industry partners
- to develop and sustain students' interest in engineering courses
- to satisfy industry demands, strengthen industry links and improve employability rate in industry
- to utilize effectively the teaching time for various courses in the curriculum

In accordance with the active learning principles stated above, it is not sufficient just to learn about professional and other issues and pass exams. The techniques need to be used in real situations by the master students and graduates. For the project-based approach, it is extremely important to emphasize the connections between different aspects, to encourage a broad-based system view and to illustrate the practical, technological and human constraints of solving the real-world problems.

The theoretical component deals with the formal theory of electric drives and power electronics. Today these theories have reached a degree of complexity that can only be managed by a lecturer. Moreover, a theoretical study does not always have to be passed before taking the practical assignments. To one part of students, it is more beneficial to acquire theoretical knowledge first, but to the other it is more reasonable to pass practice beforehand because this can provide a good basis for building the theory, thus helping students to understand some of the theoretical concepts. Consequently, multiple educational trajectories may be built that depend on student abilities and course contents and differences in the ratio of lecturing, practical and assessment classes are possible.

In our study, within the framework of the course, each student was required to design and develop, build, and test separately the personal drive unit equipped with a power electronic converter. The types of gears, motors, and power converters for the particular design problems had to meet the demands set by an instructor. To support learning, a series of problem exploration were proposed. One set of design problem examples is given in Table 1.

TABLE 1. PARAMETERS OF THE DRIVES DESIGNED

Loading mechanism	Drive composition*	Mass m, kg	Speed v, m/s	Acceleration a, m/s²	Path Δl, m	Cycle T, s
Support	gs-ms-c-φ	1500	0.1	0.2	3	35
	gs-ma-c-ω	1250	0.15	0.3	2	15
	gs-md-ct-φ	1000	0.2	0.4	1	7
Hoist	gp-ms-c-ω	300	–	–	1	6
	gw-ma-c-ω	400	–	2.0	2	8
	gt-md-ct-φ	500	–	–	3	9
Truck	gw-ms-c-ω	3000	0.6	–	–	–
	gt-ma-c-ω	2500	0.5	1.0	–	–
	gp-md-c-φ	2000	0.4	–	–	–
Conveyor	gp-md-ct-ω	250	0.7	–	–	–
	gt-ma-c-ω	230	0.5	0.3	–	–
	gw-ms-c-φ	210	0.3	–	–	–
Roll-table	gp-ms-c-ω	500	0.9	–	–	–
	gp-ma-c-ω	1100	0.5	0.3	–	–
	gw-md-c-φ	5000	0.4	–	–	–
Rotary table	gw-ms-c-φ	300	–	–	–	10
	gp-ma-c-ω	250	–	–	–	8
	gp-md-c2-φ	200	–	–	–	9
Crane	gp-ms-c-ω	100	0.2	–	0.5	10
	gw-ma-c-ω	150	0.3	1.0	0.8	8
	gt-md-ct-φ	200	0.4	–	1.0	6

Here, the required drive compositions include multiple variants of gears: gt – spur, gp – planetary, gs – ball screw, gw – worm; motor drive types: ma – asynchronous, ms – synchronous servo drive, md – direct current; converters: c – transistor, ct – thyristor; control systems: φ – with speed and path feedbacks, ω – with current and speed feedbacks.

The final design report usually includes the following results:

- request for proposal with the individual input data
- timing calculation and the mechanism travel diagram
- mechanism's forces calculation and torque/power patterns
- optimum motor-gear set selection and checking
- power electronic converter dimensioning and selection or design
- data and simulation results with transients of an open-ended system
- block diagram of the control system
- controller development and tuning
- data and simulation results with transients of a close-loop system;
- conclusion of the project summary
- appendix 1 with an operation diagram of the thyristor phase modulation or the transistor 2-phase block or 3-phase pulse-width modulation
- appendix 2 with a wiring diagram with power circuit and drive specification

To implement project-based learning, the traditional style of lectures was changed so that the behavior analysis would replace partially the formal explanation of the theory within limits. Accordingly, if necessary, practice and lab work may precede lectures; moreover, new kinds of study may appear. In the lectures, problem scenarios are presented to the students before any relevant theory or practice is given. The open problems are framed by the teacher in accordance with the topics in the syllabus and a lecturer acts as a contractor. He/She asks the students (acting as subcontractors) to design and implement a fully functional motor drive or electronic converter that covers most of the topics reviewed in the theory lessons. The first classes are spent creating a systematic design of the final product − the specifications and main functions are described, and a functional block diagram is conceived. This policy means that students find the explanation of systems and ideas to be useful because they can see the target application. In addition, the start-to-finish design, from the block diagram until the final implemented system, helps the students in the task of determining, solving and grasping the problems. Another benefit is that the students must pay particular attention in the classes in order to complete the proposed prototype. During the next lessons, the lecturer reviews the designs and products and advises the students about the possible errors or mistakes. Therefore, the teacher is responsible for ensuring that each student's design is correct and that the final prototype is a working unit. Finally, he/she also acts as a vendor as the final prototype is usually implemented on the prototype boards.

The specially prepared textbook [22] and its web release contain sections supported project-based learning. Some of the sections are intended to complement the lectures for beginners and for advanced learners, summarizing basic terms and conditions as well as the topical mathematical bases of the course. Other sections explain the broad self-learning part of the course. Calculation examples, experimental and assessment problems of the course are also provided. The multiple links connect the textbook with analogous and supplemental assignments in the field. The properly structured index and the reference list serve as the powerful navigation tool.

In addition, the assessment strategy was redefined and reformulated for project-based learning and additional evaluation methods were proposed to stimulate the learner. Particularly, the new assessment procedure invokes to evaluate

- problem statement and understanding
- learning objectives
- methodology used
- problem solution under the theoretical and practical headings
- calculations, simulation execution, and software selected
- practical results, presentations, and the printouts

An original toolbox *eDrive* opens multiple possibilities for learners and instructors [20]. It was developed to support the course in accordance with the project-based requirements as well as to assess the goals. The main features of an educational soft tool that discern it from the models meant for the professional designers are as follows:

- descriptiveness and compatibility of results
- clearness of physical essence
- suitability of report generation and format conversion
- independence of particular company interests
- matching the standards and design rules
- availability of learning-oriented manuals, textbooks, and guides

The described software offers solutions to the next typical educational and project management problems:

- informational support in electrical, mechanical, and electronic equipment selection
- mathematical and computer simulation and full computation with the use of databases
- testing and result verifying in accordance with different criteria
- drive tuning and load optimization

The toolbox includes the next components:

- powerful database
- set of adjustable controller schemes
- models of motors, converters, and gears
- graphic package for representation of the steady-state and dynamic simulated processes with an automatic and manual scaling, report generator, system analyzer, and preview facilities
- signal generator to produce the test reference and load signals as well as the nonlinear curves, noses, and filters

Thanks to the strong mathematical core, it supports all the laboratory works of the departmental curriculum. Moreover, the environment provides a possibility to simulate the same assignments using equipment of a number of companies that cannot be acquired in the institution. Comparison and discussion of the results obtained serve as a very beneficial instrument in the development of student skills and experience by using both simulations and the real equipment.

The following principles underlie project-based learning:

- students are encouraged to work regularly throughout the course and to take an active role in their learning process
- active and reciprocal interaction appears between students and lecturers as well as among the students themselves
- the course content focuses on essentials and emphasizes comprehension of overarching principles
- students are stimulated to obtain relevant concepts and knowledge from preceding courses
- students have to use the new concepts, and conceptual understanding is valued
- teaching of the new content is connected to the students' prior knowledge

Thanks to project-based learning, the staff, students as well as the community have benefited. Industry relevant projects provide students with knowledge of how theory can be related to current industrial practice. Students show a lot of interest and enthusiasm while working on projects. The work gives a holistic approach to student learning as it integrates the commercial projects with the core courses and learning objectives. Students' technical skills are tested when working on designing, building and testing the project. While designing the project, the students integrate and connect knowledge from various courses to work on an optimized solution for the mentioned problems in the project. They have to know the background theory and consider all practical issues while designing. Project design also tests the mathematical skills of the students. After designing a module, the students use software simulations to test the design before they actually build it, thus checking the ability to use computer software appropriately.

Once the module is simulated, the students build some of its components using a laboratory platform, thus obtaining their manual skills. The laboratory equipped by the leading companies in the field accompanies the study. It includes a number of test benches the most part of those supports the e-learning on-site and off-site activities [23], [24], [25].

IV. Collaborative Learning

As with any engineering discipline, Electrical Drives and Power Electronics are based on the integration of multiple fields of knowledge. Insofar as a certain number of systems with the components of different nature are merged, a conflict between technological complexity, cost, and simplicity of maintenance naturally occurs. The corresponding educational aim is to teach specialists working at the intersection of electronics, mechanics, and control. Course assignments and master's thesis are suitable tools for this kind of training.

Collaborative learning has become a necessary part of the project-based approach. To stimulate teamwork, a specific team-based methodology has been developed [15]. The goal of the collaborative design is to build effective real-world electromechanical equipment.

One of the typical course projects is devoted to the design of the robot drive system. Schematic plan of the transportation robot is given in Fig. 3. The work includes two stages: the stage of individual creativity and that of collective work, particularly via the Internet. These phases are detailed in Table 2.

TABLE 2. Stages and Disciplinary Bases of Design

Stages and items	Disciplinary base
Individual design stage	
1. Force, torque, and power computation	Mathematics, physics and computer science
2. Equipment selection	Database theory
3. Optimization of the electrical drive content	Function analysis and optimal control theory
4. Synthesis of regulators	Discrete mathematics and control theory
Collaborative design stage	
1. Composition and interrelation of axes	Linear algebra and programming
2. Trajectory description	Mathematics and numerical control
3. Motion programming	Programming, CAD
4. Estimation of the project	Function analysis, reliability, and economics

In the first part, each student designs a drive of one of the mechanisms: the carriage, the arm, the lever, or the capture. For the forces, torques and power calculations, the data of the inner mechanisms are required, thus co-operation is needed to obtain a successful result. In the second part, the intercommunications of the robot sub-systems are organized.

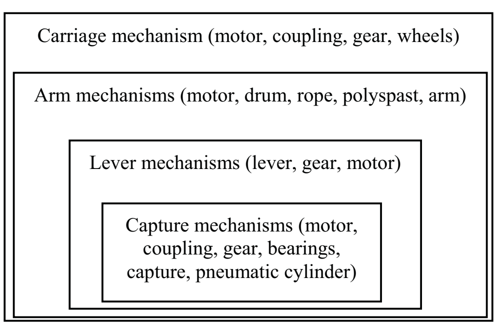

Figure 3. Schematic plan of the transportation robot

Programming of motion, efficiency, and economic evaluation depend on the joint efforts and personal solutions. The same concerns the overall estimation and project assessment.

The final and the most important part of the project is integrating the various modules and testing the overall functioning of the project. This part needs programming and debugging skills. Students learn about project management when they work on resources, timelines and procurement of components. The generic skills are tested based on students' attitude when working in teams and submitting the technical report on the project. Hence, working on a project covers all the aspects of learning.

A student group comprises usually 15 to 20 participants, randomly shared into 4-5 interaction-oriented teams with a proper mix of both academically weaker as well as stronger students. This grouping is done at the beginning of the course when the learners are informed about the practical set of the discipline that would require the study of real world systems and that the teams are a key component of the project. For each problem, the team is encouraged to elect a leader who would organize work distribution. Team leaders are appointed by the course lecturers to coordinate group activities and ensure close interaction among all team members. All teams are charged to meet regularly and to achieve the set objectives on the event driven basis. The students are assigned 12 weeks to work on the research problem. They distribute the work amongst themselves, with team members performing tasks such as searching for information from various resources, compiling the data, doing calculations, performing experiments and finally recording the work done and preparing a presentation. Ideally, these various tasks are rotated among the team members. The teams discuss issues, decide their own theoretical, practical and software goals and explore these learning and mistakes. This encouragement is given by continuous monitoring and by instructing them to record each relevant finding, any mistakes committed and the corrective action taken. Once the team members reach the solution, they are also asked to frame similar kinds of problems and identify application areas. Throughout, they are guided by an instructor who would correct students as they encounter difficulties and help them to draw conclusions to reach the desired goal.

The project is worth 30 to 50% of the final grade and the remaining 50-70% is covered in the course examination. The criteria used to score the students are listed in Table 3.

TABLE 3. Scoring Criteria

Item	Score
Problem formulation	3 – 6
Team participation	5 – 10
Minutes of meetings	5 – 6
Report	5 – 10
Proposed system design	5 – 10
Presentation	7 – 8
Total	30 – 50

As a result of the project-based collaborative learning, the average student final grade increased 1,4 times as compared to the traditional approach and reached 4,3 on the 5-based assessment scale. The students interested in active approach obtained the highest scores whereas the weak students also improved their results to some extend.

Thanks to the team-based approach, the students not only maximize their practical learning experience to achieve the project goals, but also develop other important abilities in the following:

- *self-directed learning* − as a project may involve multidisciplinary knowledge which is not covered by the standard lecture material, students are driven to study and seek solutions which serve to enhance their understanding of the theoretical material
- *project management* − students organize a task based on the talents of each group member, and each defines their own task and manages their progress against a specified timeline
- *product design* − students have more scope to develop the project so as to display their inventiveness

V. CONCLUSION

The proposed project-based collaborative learning approach encourages the reinforcement techniques that focus on a conceptual understanding and new opportunities for students to choose the content and study methods. It shows students that teaching is stimulating and caring and gives them time to process the concepts in contrast to overworking within the course or curriculum. Students who take an active approach to learning reach a higher, more integrative level of understanding and demonstrate longer retention of the material. Engineering graduates of this type have a strong inclination to apply the type of learning that forces passing the courses. Since a student's orientation to learning can be modified by the course environment, instructors have the possibility to influence which approach a learner will adopt.

ASKNOWLEDGEMENT

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Session 09D Area 4: e-Assessment and new Assessment Theories and Methodologies - Theories

Ensure Program Quality: Assessment A Necessity

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Paper-Based versus Computer-Based Testing in Engineering Education

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Methods of the quality assurance applied at remote laboratory selection

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Introducing alternative assessment into engineering language education at the Madrid Technical University

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Ensure Program Quality: Assessment A Necessity

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***Abstract*— In an effort to achieve high quality programs and courses both formal and informal measures are used the teaching and learning process through direct and indirect methods. Assessment has become even more important since education institutes show great interest in the educational experience outcomes and how they map to institutional goals as well as to the needs of the society. Institutes either develop a formal internal assessment process or through external accreditation try to continuously improve and revamp their programs. It is now perceived that students are more active in building their knowledge rather than simply listening to the lectures. Assessment of student work therefore helps us to determine the effectiveness of programs from student's point of view. This also gives an opportunity to the students to show us what they have learned and how they can contribute when they graduate. It is therefore all that important, for institutes interested in accreditation, to assess learning outcomes as a component of program review process. The accreditation guidelines in general seek to encourage institutes to think about accreditation as a continuous process and go one step further to data collection, analysis and change in order to ensure good quality program. This paper addresses the necessity of assessment through seeking accreditation and also provides a more structured mechanism for accessing, evaluating and improving the quality of the program. This paper details various assessment tools (AMS, Web-Based, Directory Structure, etc.) used by different institutes, to help in organization and gathering of the related material. The paper also presents a model for sharing responsibilities to monitor and evaluate gathered material and assessment data.**

Keywords-component; Accredidation, Assessment, Course Learning Outcome, Program Learning Outcome, Rubrics.

INTRODUCTION

Aiming for good quality programs is on the wish list for almost all the institutes. A collection of good quality courses is thus essential to ensure high quality program. In an effort to achieve quality among the courses both teaching and learning process should include assessment using direct and indirect measures. We see a widespread interest in the educational experience outcomes and their link to the goals for students, institutions and society, making assessment even more important instrument. Students at this time and age participate actively in the building of their knowledge rather than passively receive what we lecture; this gives us a better understanding of the student learning process. In that respect, assessment gives us an opportunity to evaluate effectiveness of our programs from the learner's perspective. In addition it gives an opportunity to students so they can show what they know by the time they graduate. One of the ways to ensure this is by assessing learning outcomes of the program.

In general, universities support the assessment of student learning as an integral part of their core commitment to graduate students with high value degrees. Institutes in general review their academic programs, to ensure continuous improvement, through a formal automated or manual internal assessment process. As per definition by the U.S. Department of Education, accreditation can be considered as a process by which a third party accrediting agency assures that a program meets quality standards that are established by the respective profession [4]. Generally, preparing for an accreditation visit, at regional or national level, is a huge task for everyone involved. The accreditation guidelines in general recommend not viewing accreditation as a onetime event rather it is a continuous and progressive process especially when accreditation agencies place lot of emphasis on not only outcomes and assessment, but also on continuous improvement, in order to endure good quality program.

The Accreditation Board for Engineering and Technology (ABET) USA criteria for program accreditation require that programs make decisions using assessment data collected from students and other program constituencies thus ensuring a quality program improvement process. This requires development of quantitative measure to make sure that students have satisfied course learning outcomes and consequently the program learning outcomes. Figure #1 show this cycle of continues growth and improvement involving activities like revising program learning outcomes (PLOs), course learning outcomes (CLOs), and assessment leading to yet further improvement in program.

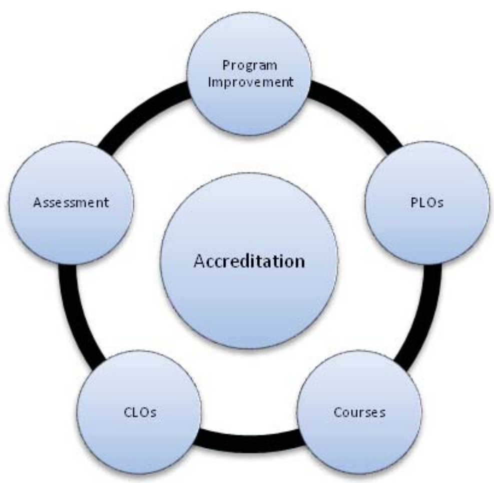

Figure #1 Accreditation and associated activities

We argue that seeking accreditation is a desire that leads to providing a very structured mechanism that helps to assess, evaluate and eventually improve the quality of the program. Following sections detail various assessment approaches used by various institutes seeking accreditation, emphasizing that computer assisted assessment would help in organization and gathering of the related material. A brief review is provided of different tools (AMS, Web-Based, Directory Structure, etc.) that can be used for assistance in collecting data for program assessment. The paper also presents a model for sharing responsibilities to monitor and evaluate gathered material and other assessment data.

PROGRAM LEAD

The latest trend of getting institutional accreditation, for all the academic programs has sparked a greater interest in assessment. However, since majority of the faculty members are not too keen to get involved in the assessment process, mostly because they are not familiar with the assessment process and/or the methods used, so we need to explore avenues by which faculty can be engaged actively in the assessment of a program, at college or university level. The new accreditation standards for computing, technology and engineering disciplines put a lot more emphasis on course and program outcomes, assessment activities and continuous improvement in their statements of intent [10, 13]. This provides justification for an approach to get the entire faculty involved in the assessment process, while mapping outcomes and other collected data against expectations. Later each faculty member can plan curriculum revisions based on the analysis of this data. These curriculum revisions and developments, from accreditation perspective, can be seen as a part of continuous assessment process [12].

In order to establish clear criteria against which a program needs to be evaluated, one needs program learning outcomes (PLO) that are clearly stated. In addition course learning outcomes (CLOs), statements of student learning as well as development expectations are also required. All these will help to determine the basis for future program planning [7]. Clearly stated PLOs also serve as a guideline for the faculty teaching the course to be aware of the knowledge and skill set needs to be developed by the students. In a broader sense these objectives not only provide basis for curriculum development and revisions but also for selecting the faculty to teach the course. The PLOs therefore should be relatively stable over time however, at the same time be expected to change because of the results from assessment activities. In general, the stated assessment objectives are quite similar to these PLOs. For the sake of not overburdening the faculty with extra task it is recommended to not assess all of the program learning outcomes in one given year. It therefore leads to establish a set assessment schedule to make sure that all of the given program learning outcomes are assessed by the end of 4-5 year cycle and before the institute decides to seek accreditation.

In an effort to have faculty involvement and understanding of accreditation and assessment we propose the concept of assigning a faculty to be the program lead with the understanding that this person will be responsible for not only staffing the courses in the program but also for leading and organizing annual assessment of the program. A single person responsible for such an activity would lead to a more focused approach to assessment and more involvement of the faculty in the process of assessment itself. The lead faculty will also ensure PLO and CLO mapping and thus further revisions of CLOs and courses as well as, other assessment related activities. Departments establish their mission statement and the program leads will define their own program goals and determine how they are to be addressed, form an Academic Program Assessment Advisory Board or committee that provides timely feedback to facilitate the assessment process and help revise and improve program. The emphasis of assessment is on program evaluation to improve student learning, and to further a culture of student learning; assessment measures are employed to help achieve that goal. Therefore, for assessment to be effective and helpful, results obtained from various assessment activities need to be utilized to further develop new programs and improve existing programs. Finally, assessment results can also be helpful in decisions regarding resource allocations and reallocation for the program.

III. ASSESSMENT

The assessment's role is to determine what a student can gain at various levels of a learning experience in typical educational setting or environment. There are two types of assessments, formative and summative assessment [3]. Formative assessment, determines the incremental out comes and occurs during the entire learning process. Summative assessment on the other hand determines more holistic and integrative outcomes at the end of the learning process. Assessment data collected during various stages are subsequently used for multiple purposes, as stated in [3]: (a) Management and monitoring of instructional part (b) Evaluation and accountability of the program (c) Placement and selection of students in the program. The information gathered from assessment activities is then utilized to develop a model of the student's ability to evolve a conceptual knowledge structure keeping in mind the target structure. Assessment provides means to focus our collective attention for examining assumptions that we have made and our efforts in creating a kind of a culture that is dedicated to improve the quality of higher education and associated learning. The assessment exercise requires that all of the expectations and standards, established for the program, be announced and available to public. It also needs that evidence be gathered systematically from time to time to determine how well these standards and expectations are being met. At the same time the analysis and interpretation of the gathered evidence data can be used to document the achieved performance, explain any shortcomings and to further improve the performance [14].

IV. ASSMENT: THE PROCESS

As Gloria in [2] states that, it is important that one understand the question before being able to come up with the correct answer. Similarly we should try to think about the questions related to assessment process in connection with accreditation and program effectiveness. This exercise is very important since we may generate lot of random activities for collecting material that we do not need after all. So it is important to understand the question being answered and its implications on the assessment process design. A program or a department should first try to create mission statement to describe the programs in the whole department. A program can then establish its goal and learning outcomes. These outcomes basically describe what students should be able to do by the time they graduate from this program. In order to verify that the graduate do actually have these attributes a thorough analysis of the student work (Written assignment or class project or capstone project) can be used as a direct assessment method to access program learning outcomes and goals. In order to quantify program indicators it is always beneficial to develop and use rubrics to measure student performance which ultimately leads to the measure of the program effectiveness. For example, a program outcome can be divided into various components. Later, each of these components can be evaluated using one of the developed rubrics. Finally merger of all of these individual components will lead to assess a range of program learning outcomes [4].

The assessment process begins when programs identify Program and Course learning goals and outcomes. In most cases goals are finalized based on both faculty expertise and requirement of the professional or accrediting agencies. Once learning goals are established, the departments and programs devise ways of measuring or assessing how well students are meeting those learning goals. These assessment methods most often directly measure student learning and are frequently embedded in courses offered in the program, including capstone courses. Appropriate assessments may also include indirect measures like employer surveys, alumni surveys, exit surveys or interviews and rates of enrollment to advanced degree programs. Departments analyze these data, identify strengths and challenges of the programs, and make appropriate changes to improve their success at achieving program learning goals. Program also need to evaluate their success in other critical areas, such as, meeting the needs of the general education program, offering service courses, and other functions that serve the university's broader mission [9].

Figure #2 shows the activities required to ensure a high quality assessment process that requires direct and indirect measures of the course and program learning outcomes as well as input from the advisory board. All these measures are vital both for credible assessment process and program quality.

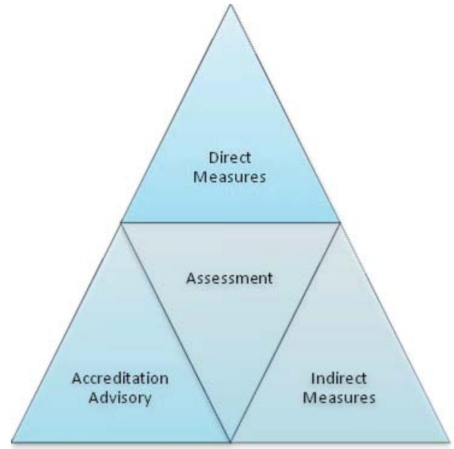

Figure #2: Quality Assessment

University graduate or undergraduate council, at most of the universities, is responsible to oversee assessment of each individual program. This council is also responsible for conducting the Annual and Five-Year Program Reviews to ensure quality and consistency among various programs offered by the university. Among its other assignments the Graduate or Undergraduate Council also examines the main components of assessment plan for each program, particularly student learning and program outcomes. For the purpose of review and assistance in the assessment process of the annual and five year assessment, each graduate or undergraduate degree program is required to provide information on [5]: (a) educational objectives of the program; (b) measures to evaluate success in achieving these objectives; (c) the goals that are being successfully met in addition to those that need attention as determined by the analysis of the gathered data; and (d) how assessment data is used to improve quality of the program.

V. Direct and Indirect Measures

These measures are considered as the primary source of data in assessment of a program. To ensure consistency as well as equal quality and rigor in all of the courses in the program [7] suggests writing a Program Quality Improvement Report (PQIR) by each faculty member teaching in the program. The report contains (1) Assessment data displayed, (2) a complete analysis of the assessment data, (3) evaluation of the conclusions regarding course strengths and weaknesses, (4) course modifications as a result of analysis of the assessment data. These modifications may be in goals, objectives, or strategies (5) modifications proposed for course improvement, (6) projected time lines for implementation of all the suggested modifications, (7) any additional resources requirement estimation for implementing recommended changes, (8) assessment methods evaluations, and (9) the annual assessment plan update. In our proposed setup, all of the PQIRs are then analyzed by the program lead for an academic program and approved not only by the program lead but also by the Chair of the department, the Dean of the Academic School or college, and the provost. Collective PQIRs can be used as the basis for initiating any actions aimed at improving the corresponding individual academic program.

The capstone experience becomes a very effective direct measure if it is clearly linked with the identified learning outcomes. This can be achieved when standards are carefully structured and documented, with well defined rubric for written and oral communication. A very qualitative internal and external review of senior project can be used to legitimize the entire capstone experience and evaluation. Among other means for direct measure are; Student performance on certification or professional exams, for internship an external evaluation, based on stated program objectives, of performance. For indirect measures; alumni, employer, and student surveys, exit interviews or survey of graduates, graduate taking higher degree programs, length of time to graduate, job placement can be used as indirect measure for the program quality. Assessment process also include the faculty and staff members input to the process when the next year's academic plan is prepared by the department chairs in consultation with the faculty and staff outlining realistic budget requests, including both operating and personal costs. Figures #3 outlines different components of the assessment process.

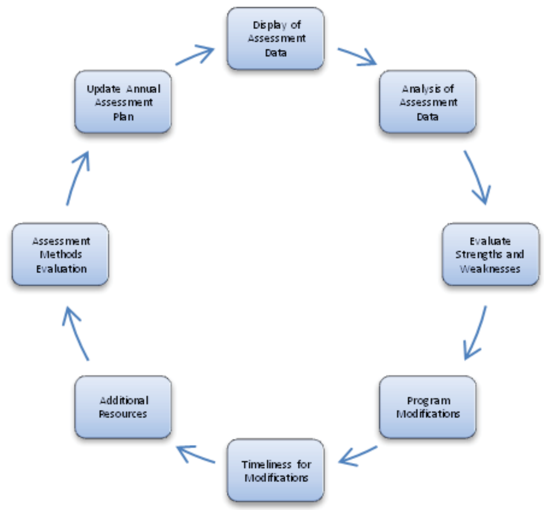

Figure #3: Assessment Process

VI. ASSESSMENT TOOLS

To prepare for an accreditation visit generally involves lot of preparation work and hence is viewed as a huge task. However, the accreditation guidelines suggest that accreditation should be looked at as a continuous process; an iteration of data collection, analysis, and modifications. The accreditation should not be viewed as a onetime event. Authors in [10] report a prototype system to automatically map ABET-CAC's outcomes to the department and course learning outcomes for Information Technology Programs. In this system students are required to submit their work through the web, these assignments are then mapped to program and course outcomes. Program as a whole or an individual course is then revised using the assessment data. Assessment methods and tools cover the measurement options that can be used for each program learning outcome; which courses are to be considered based on the PLO to be assessed in a particular year; assessment data collection and analysis needs to follow a certain time line; analysis methods used on the collected assessment data; formulate conclusions from the analyses results drawn using a certain rubric or criteria. Rubrics are used in assessment as a good technique to improve communication and feedback between faculty and students. Faculty use rubrics to relate the contents that they want to evaluate with some feedback, taking into account the possible results of the students in an exam, work or exercise. Learners use rubrics to know which topics they have to improve and why [20]? The assessment model in [7] relates program strengths and weaknesses to conclusions concerning student weaknesses and strengths. Each analysis method and the assessment data collection is evaluated every year using assessment results. Then suitable modifications and updates are included in the program for the next year's assessment cycle.

There are many assessment tools proposed by researchers and practitioners with the aim of facilitating faculty by using good techniques for assessment. A research line of interest in technology enhanced learning is focused on integrating good assessment techniques in Computer Assisted Assessment (CAA) [17]. It enables the provision of formative feedback to students in a more efficient way than with the traditional assessment. A user-friendly assessment editor helps faculty in the design of eQuestionnaires and rubrics. Brinke et al. [16] propose an educational model for CAA where rubrics are used in the response stage of assessment when reviews of assessment material are evaluating program learning outcomes. [11] proposes a novel more interoperable solution supporting interoperability through the IMS Test Interoperability specification (QTI) specification [18], by using rubrics more extensively, and enhancing user support through a new editor implementation. In this paper, they add an editable rubric functionality into previously implemented QTI compliant eQuestionnaires CAA editor [15]. By means of this functionality, faculty can create a rubric using QTI *questionsItems* ((re)using existing items or creating new ones), and relate them with the assessment activities they want to evaluate and the grades and feedback they have to assign depending on the students' results (which are facilitated by the use of QTI).

The North Carolina Agricultural and Technical (A&T) State University has been experimenting with standardized exam questions in their chemical engineering program. In this effort a large database of questions has been created. These questions are prearranged by CLOs, difficulty level and type of questions. The questions are made available to students via WebAssign® (a web-based homework system) [1]. The statistical analysis of student performance validates these individual questions in the database. This assessment tool further supports the idea that the assessment should create minimum extra work for the faculty. The tool will quickly and easily provide assessment data to the individual faculty in the program. It is understood that faculty will adjust both their teaching style and the course material by using this readily available assessment data. This will also help them to meet two objectives; be well informed to advice students who may not be willing to take such a course and to satisfy student's demonstrated needs. An alternate assessment instrument used for design learning is reported in [3]. The paper presents three tools (portfolios assessment, cognitive maps and a writing technique called "freewritng") for assessing a freshman level Introduction to Design course based on the development of design skills and knowledge.

VII. Assessment Model

It is important that program faculty is involved in every step of the assessment. This is the basis for the design and development of the assessment model presented in this section. The faculty has a key role in the decisions regarding the control and development of the data collection. The committee level involvement to monitor and control course and program development is also essential. Faculty should be free to make any kind of decisions regarding program and course improvement, this also ensures academic freedom. The Accountability Management System (AMS) by TaskStream [21] provides the tools to assist educators for uploading the data required to show institutional effectiveness. AMS is a system that can be modified to help facilitate and manage institution-wide strategic planning and assessment initiatives to strengthen teaching and learning. Institution and program level learning goals can be documented and managed through the use of AMS by universities and colleges. Activities at the program level are planned to define essential student skills and for measuring performance out comes using institutional learning goals. The results of the student achievements, institutional goals and initiatives and community participation collectively provide new powerful ways for the demonstration of effectiveness and improvement over time.

For all of the institution's initiative regarding outcomes assessment and continuous improvement AMS provides a resource and communication center. It also helps in promoting communication and collaboration among campus wide community. Great communication and collaboration capabilities of AMS also allow university management and administration to share with third party stakeholders' access to the entire accreditation process. Educational excellence culture is effectively promoted when both administrators and faculty use real time activity status reporting facility of AMS during the entire assessment process. Faculty and other administrators do not any more need to document the entire accreditation process on papers. The system will allow them to effortlessly add their comments, detailed instructions and already agreed templates. Accreditation agencies can utilize online reporting capabilities of the system if given access to this system by the institution. Real time access to data allows faculty to analyze, recommend or implement changes in a timely manner.

Accreditation as well as reporting process is facilitated and accelerated because of the instant feedback provided due to the review of the contents and reports provided by the online content and documentation review capability of the system. Program faculty can define their own program learning goals for a specific program using objective and learning outcome definition facility provided in the system. This assessment model helps in building an agreement among the faculty and administration regarding defining PLOs, assessment planning, analyzing results and then later implementing the changes based on this analysis. It also allows use of appropriate terminology as well as terminology to customize templates and thus making using of the system even easier. Curriculum mapping, courses (Course Learning Outcomes) versus PLOs, provides a clear indication to all the strengths and weaknesses in the program. Any gaps in the curriculum are also exposed through this mapping.

Figure #4: Assessment Model

Programs under consideration for accreditation need to participate in all of the program assessment activities. However, in most of the cases the faculty with the responsibility to get the program accredited asks this simple questions where do I get started? The response to this question is very simple and straightforward just follow these steps;

Develop plan: Start with identifying the program learning objectives or out comes, criteria and measure for the program.
Program Input: Insert all program related data to the system.

Implement your plan: During each academic year assess your programs based on selected program learning outcomes for that year.

Report your results: All the data from the program assessment should be reported to the system using assessment tool.

Close the Loop: This is the most important step in the accreditation process. Once the assessment results are available examine the data. The analysis of the result will help you determine if changes in curriculum (or instruction) are required. Once these changes have been implemented start your assessment again.

The use of any assessment tool to facilitate assessment activities will still need to follow a certain assessment model. Figure # 4 present a assessment model that ensures faculty involvement at every step either as teaching faculty, assessment committee, or at the top as undergraduate or graduate council.

VIII. CONCLUSION AND FUTURE WORK

The work proposed in this paper represent a preliminary approach towards the use of assessment in combination with various tools as a useful method to organize assessment information and to provide automatic formative feedback, so that assessment activities can be meaningfully embedded in learning flows. Results from this study suggest that although participants in the assessment process generally accepted the responsibilities in the assessment process, they did not necessarily fully appreciate the potential benefits of assessment and reflection activities. Thus, it is apparent that greater effort, further support in the form of tutorial input, extended explanation are needed to embed the assessment process as part of the learning culture. We are also aware of a need to revise assessment approaches in relevant courses. The overall aim of such revision is to reassure participants that formative and reflective assessment is a safe and effective means for improving courses and programs. This paper presents some of the prominent features for most effective and efficient assessment process. The paper also describes the important step to serve as a guide for the faculty member who wishes to engage in the accreditation and hence assessment of their programs.

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Paper-Based versus Computer-Based Testing in Engineering Education

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Abstract-- **Using computers for assessment can provide several benefits for educators and test-takers. However, in the literature, there is no consensus on the equivalence of paper-and-pencil and computer-based test environments. Accordingly, more evidences are needed especially for the engineering education. In this study, students' performance on different test modes was evaluated on 209 first year engineering students of a chemistry course. The results of this study showed that, there is no significant performance difference between paper-and-pencil and computer based tests. By comparing results with the previous studies, this study concludes that, personal characteristics of test takers, the features of computer-based testing systems and the test content are all possible confounding factors when comparing test modes and need to be considered by the implementers. The results of this study show that, once these factors are controlled, students' performance on computer-based tests and paper-and-pencil tests in chemistry courses for the engineering students will not vary. This finding is encouraging the educators to get benefits of computer-based tests without any affect on students' performance.**

Index Terms— Computer based exams, Test-Mode Effect, Paper-and-pencil Based Exams, engineering education

I. INTRODUCTION

Exams are an important instrument of student assessment. As stated by Brown, Race and Bull [1] the style of assessment can have an important influence on student learning. It has been suggested that if an aspect of a course is not assessed, students will probably not learn it [2]. Hence, assessing students' performance is always an important issue for educational systems. Depending on the number of students, it is not easy to implement such techniques more often. In that sense, Computer Based Testing (CBT) systems can provide alternatives for implementing tests more often on different educational settings.

Even though there is a trend toward alternative assessment methods, CBT is definitely in ascendancy, especially in distance education, certification, and licensure [3]. According to Sawaki [4], in order to support construct validity of computerized tests such that the construct being measured is not being affected by the mode of presentation, the equivalence of corresponding conventional and computerized test forms must be established from various direction. According to Ricketts and Wilks [5], issues related to student performance should be carefully considered when computer-based assessment is introduced. According to them, mode of presentation of assessment can significantly influence student performance. Questions about differential impact of paper-and-pencil (P&P) versus CBT on test performance are referred to as test mode effects.

The literature has contradictory results on the CBT vs. P&P tests. For example, there are some studies showing that there is no significant performance difference between P&P tests and CBT [6]-[14]. Among those studies, Ashton et al [14] have analyzed the medium effect (the screen dumps of the computerized version vs. computerized version of paper test) and rewording effect (original paper test vs. computerized version of paper test). They could not find any evidence of either medium effect or rewording effect.

However, results of some other studies showed that, students perform superior on the P&P test than the CBT [15], [16]. Contrary to these findings, in some cases students benefit most from CBT compare to P&P based tests [17]-[20].

By analyzing the findings in the literature, we can categorize main confounding factors when comparing test mode as: personal characteristics of test takers, features of computer-based testing systems and test content. The related literature shows that some personal characteristics of test takers may have impact on students' performance on different test modes. There are some studies showing that gender, socioeconomic status and computer experience affect performance on computer based testing [15], [18], [21]. For example, results obtained from 1,114 examinees that completed computer and P&P versions of the Graduate Record Examination indicated that the overall performance of male examinees on the computer version was better than would be expected from their paper scores, whereas female examinees performed better on the paper version than their scores on computer version [22]. Although gender does not interact with mode of test administration for relatively low-stakes tests such as psychological assessments, gender differences in perceived self-efficacy regarding complex computer tasks are evident in other studies [22], [23]. It may be possible, however, to decrease gender differences by preparing female students for complex computer tasks. Consequently, female students with more experience in relevant computer tasks may feel more prepared for high-stakes, complex computer tasks. Specifically, female students with CBT experience most likely feel prepared for CBT [24]. Computer anxiety is considered one of the significant factors that would have negative effect on students' performance in computer-based testing [25]. Bugbee [3] pointed out that computer anxiety, combined with other things like test anxiety, computer experience, may influence the test taker. On the other hand, for some studies, computer experience and anxiety about using computers are not confounding factors for the test-mode effect [26]. When considering the mode of presentation, Noyes, Garland and Robbins [27] found that cognitive workload associated with P&P and CBT tasks can be another test-mode effect. They found that, the computer-based test should require more effort compare to the P&P tests.

Some features of a CBT system such as the reliability of the CBT system, abilities of the system, user interface design of the system, font sizes and font types can be another confounding factor. Supportive exam types such as essay type or multiple choice types as well as the evaluation procedure of the exam can all be considered in this category. For example, Bodmann, & Robinson, [11] did a research on user interface design of CBT systems such as various levels of flexibility to change and review answers. The results of this study show that, students completed the least-flexible mode faster than the other two modes [11]. In that context, Ashton et al [28] have used a tool called PASS-IT, which is capable of giving partial credits for mathematical calculations. In this study, they have shown that, testing platform which uses technology in a proper way, have minimized the effect of test mode on test takers' performance for the partial credit mathematical exams. Ricketts & Wilks [5] also showed that presentations which require scrolling are less acceptable than those in which questions are presented one at a time.

Test content should also be considered as another factor affecting test performance in different test-modes. For example, Russell [15] found that about 20% of the students who performed the math test on computer indicated that they had difficulty showing their work and/or needed scrap paper to work out their solutions. Another issue is the reading speed of the test takers which also can be related as test content. Generally, the literature review suggests that reading from computer screen is slower than that of on paper, which may positively or negatively affect test performance. For example, high rates of online reading speeds are positively correlated with good performance on the CBT TOEFL subset of reading comprehension [29]. In that sense, if the test content requires long reading passages, then reading speed of the test takers need to be considered as well.

From the review of the literature, we understand that, both modes of tests (CBT and P&P) are some how different from each other and there is no consensus on the equivalence of P&P and CBT. Additionally, there are not many studies in the literature that focus on the engineering education students. On the other hand, many characteristics of engineering students and engineering education systems need to be considered for this specific domain. In order to better understand the factors effecting test mode for the engineering students, we need more evidences. Accordingly, this study aims to evaluate and compare engineering students' performance on P&P and CBT.

II. Research Methodology

This study was conducted within 209 students. Main research question of this study is,

Do engineering students perform better or worse on computer based test compare to paper and pencil test?

Students took three midterms and a final exam during the semester. In order to answer the research question, in the second midterm, the students were randomly divided into two groups according to their last names. The first group of the students (96 students) took the CBT version; whereas the second group of students (113 students) took the exam in P&P form.

The students did not have any practice on the computer-based exam interface before the midterm exam. After the exam, interviews were conducted with 7 students (2 female) who have taken CBT. Each interview took 45 minutes and they were held during the following week of the examination. Students were asked several questions about their feelings and opinions of the CBT that they had taken. In addition to this, an interview was conducted with the course instructor, to get her comments about both versions of the exams. Each interview session was recorded by a tape recorder and later transcribed by the researcher. To measure examinee characteristics such as gender, department, computer ownership, computer experience and CGPA, a questionnaire was used. On the test day, students first completed the questionnaire and then took their exam either on computer or on paper.

A. Course Description

In that university students are thought and examined in English. General Chemistry course (CHEM102) is a service course in our university, which is offered for all first year engineering students. The content includes introduction to atomic theory, chemical stoichiometry, thermochemistry, electronic structure, molecular structures, gases, properties of solutions, chemical kinetics, electrochemistry, and introduction to thermodynamics. The course has two parts: theoretical and laboratory. The theoretical part covers 51 hours of instructions during the semester. The laboratory part covers 7 experiments in total. The instructor teaches the class in lecture format and assessment is made by 3 midterms, one final exam and laboratory assignments. Multiple choice or short answered questions are selected from each topic in order to cover whole chapter.

B. Midterm Exam

The second midterm exam covers thermochemistry, electronic structure, molecular structures and gases. There were 20 multiple choice types of questions in the exam. Students were asked to select the most appropriate answer among the given five different choices for each question. Most questions did not require mathematical calculations, however for a few questions students needed to make some mathematical calculations. Students were also given the periodical and the Molecular Geometries Based on VSEPR Theory tables (supportive materials) to be used to answer questions.

Both exams (P&P and CBT) were organized in the same way. However, in the computer version, there was only one question on each page, whereas in the P&P version of the test there were approximately five questions on each page. The supportive materials were provided as a web-link (Figure 1) in the computer version whereas they were provided as separate pages in the P&P version. Both exams were limited in time and the students were asked to finish it in 90 minutes. We have offered the second midterm in both versions by switching the groups in order to provide both groups a fared equality in the course. However, we did not consider the results of the second midterm in our study.

As shown in the Figure 1, the computer-based exam page is divided into three sub-windows. Students can always open a new window to reach the supportive materials by using the left window. In the right window, students read each question, type the answer for each question and by using the navigation buttons they can move around questions. By using the bottom window, students can finish the exam and submit their exam results to the server.

The question numbers are not shown on the screen. Font types used in both versions of the exams are the same. Both groups of students were provided some extra empty sheets of papers to make necessary calculations. Figure 2 shows the P&P version of a sample exam page.

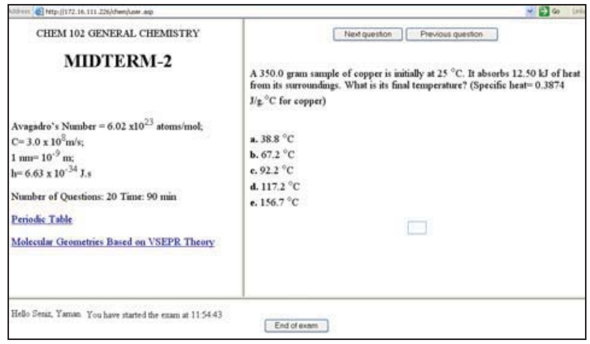
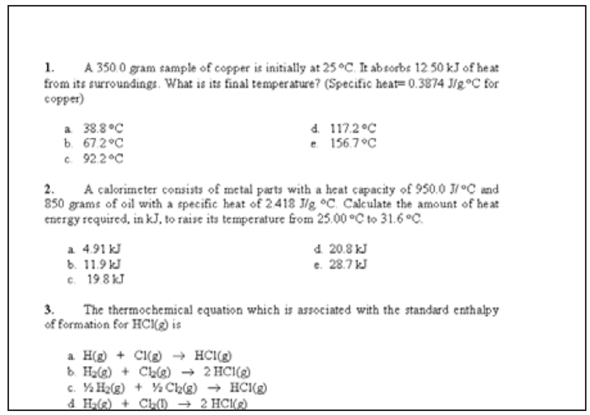


Figure 1. A Sample CBT Exam Page



1. A 350.0 gram sample of copper is initially at 25 °C. It absorbs 12.50 kJ of heat from its surroundings. What is its final temperature? (Specific heat= 0.3874 J/g.°C for copper)

a. 38.8 °C
b. 67.2 °C
c. 92.2 °C
d. 117.2 °C
e. 156.7 °C

2. A calorimeter consists of metal parts with a heat capacity of 950.0 J/°C and 850 grams of oil with a specific heat of 2.418 J/g °C. Calculate the amount of heat energy required, in kJ, to raise its temperature from 25.00 °C to 31.6 °C.

a. 4.91 kJ
b. 11.9 kJ
c. 19.8 kJ
d. 20.8 kJ
e. 28.7 kJ

3. The thermochemical equation which is associated with the standard enthalpy of formation for HCl(g) is

a. $H(g) + Cl(g) \rightarrow HCl(g)$
b. $H_2(g) + Cl_2(g) \rightarrow 2\,HCl(g)$
c. $\frac{1}{2} H_2(g) + \frac{1}{2} Cl_2(g) \rightarrow HCl(g)$
d. $H_2(g) + Cl_2(l) \rightarrow 2\,HCl(g)$

Figure 2. A Sample P&P Exam Page

C. Participants

The participants of this study were first year engineering students (from software engineering (SE), Manufacturing Engineering (MFGE), Mechatronics Engineering (MECE), Civil Engineering (CE), Industrial Engineering (IE), Electrical & Electronics Engineering (EE) and Computer Engineering (CENG)). Before taking this course, the previous semester, all of the students have completed a computer literacy course which is offered as two hours theoretical and two hours laboratory sessions in each week. The content of that course covers an overview of information technology, hardware and software components, CPU, peripherals, I/O devices, primary and secondary storage units, data communications, networks, and Internet. Word processing, spreadsheets, presentation software, and Internet applications are also introduced during the laboratory hours.

As shown in Table 1, 35 female and 174 male students participated in this study. Since in engineering departments the number of female students is usually lower according to the male students, this situation is also reflected in our sample as well which is very usual for the engineering departments.

Table 1. Students' Profile - Gender

Group	Female	Male	Total
CBT	16	80	96
P&P Test	19	94	113
Total	35	174	209

Table 2 summarizes students' distribution among the departments. Most of the students were from industrial engineering (IE) department. Among the students who have taken the CBT, only 10 of them were from computer engineering department. The rest were the students from other engineering departments.

Table 2. Students' Profile - Departments

Group	SE	MFGE	MECE	CE	IE	EE	CENG	Total
CBT	2	14	2	18	37	13	10	96
P&P	2	11	10	14	47	13	16	113
Total	4	25	12	32	84	26	26	209

III. RESULTS

In this section the results of the study presented in two parts: quantitative and qualitative.

A. Quantitative Data

The study was conducted at a private university. Compare to public universities, students' socio-economic status (SES) is higher in private universities of Turkey. As shown in Table 3, most of the students (203 students, 97%) have reported that, they have their own personal computers.

Table 3. Students' Profile – Computer Ownership

	Yes	No	Total
CBT	94	2	96
P&P Test	109	4	113
Total	203	6	209

In order to better understand students' computer experience, some questions were asked in the questionnaire. Students' responses on these questions summarized in Table 4. Majority of students like computers (79%), use computers very often (83%), use the Internet and web applications (85%) and access their e-mails very often (94%).

Table 5 summarizes the averages of Cumulative Grade Point Average (CGPA) for both groups. This shows that, the average CGPA of computer-based test group is slightly higher than P&P group. However in general, the female students' average CGPA is higher than that of males.

Table 4. Students' Profile – Computer Experience

Question	Students' Response
I use computers every day	173 (83%)
I frequently use the Internet and web applications	178 (85%)
I like computers	165 (79%)
I often access my e-mail	196 (94%)

Table 5. Students' Profile – CGPA

Group	Mean	Std. Deviation
CBT	1,34	0,86
P&P Test	1,13	0,75

An independent t test was conducted to evaluate if there is a statistically significant difference according to their CGPA between two groups. The result was not significant, $t(206)=1{,}86$, $p=0{,}064$. Students who have taken the exam on computer ($M=1{,}34$, $SD=0{,}86$) on the average have close CGPA with the students who have taken the exam on P&P ($M=1{,}13$, $SD=0{,}75$).

In the second midterm, 96 students took the exam in the CBT form, while 113 of them took the exam in P&P version. Table 6 summarizes the exam results.

Table 6. Exam Results

Test Mode	N	Mean	Std. Deviation
CBT	96	42,96	20,10
P&P Test	113	40,08	19,28

The average exam score of students who took the exam in CBT form is slightly higher than the P&P group. An independent-sample t test was conducted to evaluate if there is a significant difference between the exam results of these two groups. The result was not significant, $t(207) = 1{,}055$, $p= 0{,}77$. On the average, the students who took the exam on CBT form ($M= 42{,}96$, $SD=20{,}10$) had similar grades as the P&P group ($M=40{,}08$, $SD=19{,}28$).

A 2x2 ANOVA was also conducted to evaluate the effects of test mode (CBT or P&P) and gender on students' midterm scores. Means and standard deviations for the exam scores as a function of the two factors are presented in Table 7.

Table 7. Gender Effect

Gender	Test Mode	Mean	Std. Deviation
Female	CBT	53,38	18,54
	P&P Test	50,26	20,51
Male	CBT	40,88	19,85
	P&P Test	38,02	18,46

The results of the ANOVA indicated a non significant effect for test mode, $F(1, 209) = 0,69$, $p=0,40$. Results also indicates a significant effect for gender, $F(1,209) = 12,01$, $p<0,01$. However, the results indicated a non significant interaction between test mode and gender, $F(1,209) = 0,001$, $p=0,97$. Female students were more successful in the exam than the male students. However, the test mode (taking the exam on computer or P&P), did not effect this result.

B. Qualitative Data

The results of interviews are also supporting the quantitative results. During the interviews all students have reported that they use computers at least one hour in a day. Even two students have declared that they use computers more than 7 hours in a day. When we asked what they think about taking the exam on computer, three students said that, at the beginning they felt uncomfortable, however after ten minutes they got used to the system and they felt better. For example, one student said, "For the first 5 minutes I worried a little if I would accidentally press a wrong button. Because it was my first time to take the exam on computer. However, 5 minutes later I started to feel better". Another student also reported:

The P&P exams are what we have used to. However, taking the exam on computer is something very new to us. For this reason at the beginning I was in panic. After 10 minutes, I continued the exam as if I am taking it in P&P format.

Parallel to this, another student also declared that taking the exam on computer or paper does not affect his performance:

Taking the exam on computer or on P&P does not matter. They are the same. In both versions, you have to use paper to make some calculations. Once you know the concepts that the exam covers, they are the same. However, for those who are not familiar with computers it is normal that they feel a little bit uncomfortable. I liked the idea of taking the exam on computer.

When we asked them, what would happen if they had taken the exam on paper, all of them said that their grades would not change. For example according to one student, his exam grade would also not change. He said:

My grade would not change. The content is the same. It was easy for me. It is an exam, taking it on computer or on paper are the same.

When they were asked which format is better, taking the exam on computer or on paper, 6 of them declared that it does not matter, but two of them preferred computer version. For example one student said,

I think taking the exam on computer is easier and better. In fact they are the same; we only look at the monitor instead of the paper. For the next time I would prefer to take the exam on computer. Because reading the questions one by one on the screen increases my concentration on each question.

Another student prefers to take the exam on computer. He said, "I would like to take all of my exams on computer". One student said, "I would not say no for both of them. However to be sure, I would prefer the P&P version. You may face with some technical problems on the computer environment, such as loosing the Internet connection etc."

Since students did not have any experience with the CBT system, at the beginning they were not very comfortable with it; however, after some time they felt better. They also said, this did not affect their scores. And finally, all students believe that their performance would not change if they have taken the exam on P&P form.

IV. DISCUSSIONS AND CONCLUSIONS

In this study, data were collected and analyzed to better understand the test mode effect on students' test performance. The subjects' socioeconomic status were high, most of them were computer owners and computer literate. The results of this study show that, students' performance on the CBT and P&P versions of the exam does not differ significantly. The qualitative data also supports this result. All students declared that, their exam grade would not change if they had taken the exam on paper.

In this study, there were some differences between the computerized and P&P versions of the exams (i.e. number of questions in each page and question numbers). However this difference did not affect the test results significantly. This result supports findings of Ashton [14] which they could not find any evidence of either medium or rewording effect on test mode.

Gender effect was also tested and we could not find any relation between gender and test mode.

The results of this study supports the results of several studies which have found no significant difference on students' scores in CBT and P&P testing environments, [6]-[14], and [28].

The result of this study is contradictory to some of the results found in the literature. For example, Lee and

Weerakoon, [16] and Russell [15] have found that, students perform better on P&P based tests than the CBT. However, they have also reported that, their subjects have little computer experience. For example, Lee and Weerakoon [16] reported that 27% of the students had moderate to high experience with email and 37% of students having moderate to high experience with the web. However, in our case, students have declared that they frequently use the Internet and web-based applications (85%) as well as they frequently access their emails (94%). Similarly, in Participants of Russell's study [15] subjects did not have a great deal of experience working with computers. We believe computer experience of test takers is a confound factors when comparing test modes.

The result of this study is also contradictory to the results of studies which have found that students' performance on CBT is higher than that of P&P [17]-[20]. However, Clariana and Wallace [19] have conducted their research on "Computer Fundamentals Course" which covers the fundamental concepts and use of a computer system. Similarly, Bocij and Greasley [18] conducted their research on elementary courses in Information Systems, Computer Science and Information technologies. We believe that, in courses teaching about computer systems, asking questions in computer could benefit students to better visualize and understand the question and this may positively affect their performance on the test.

On the other hand, Bugbee and Bernt [17] could not rule out substantial differences among the groups that have taken the exam on different exam modes. This may cause the performance difference between the test modes. Pomplun et al [20] conducted their study on a speeded reading comprehension placement test. They have also reported that, the main reason for the higher scores on CBT could be the clicking a mouse which allows an examinee to move quicker through the items than when forced to record answers with a pencil on a bubble sheet.

This study shows that, while considering the test-mode effect, characteristics of test takers, features of computer-based testing systems and the test content are possible confounding factors when comparing test modes. Once these parameters are controlled, on CBT, similar test performance can be reached with the P&P tests. This result is very promising to better get benefits of the CBT environments in classical and distance learning environments. Accordingly, once the CBT environments are decided to be set, the possible confounding factors such as personal characteristics of test takers, the features of computer-based testing systems and the test content need to be controlled.

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Methods of the quality assurance applied at the remote laboratory selection

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Abstract—**Quality assurance principles applied at the remote laboratory network there are similarly with the same principles applied at the production process, which has as a result products used by society. Remote experiment is a product used by learners, a part of our society, with the main reason to increase the quality of knowledge. Learners are the consumers (the clients) and teachers are the producers.**

At limit, one student must to open all of the remote laboratories referred at the same experiment to be able to declare that his knowledge and image about this experiment there is complete. But, similarly with the classic production process, there are a various grades or levels of quality. These differences are the result of the *intentional* design of the experiment, determined by the level of the laboratories endowment, of the level of Internet connection, the type and complexity of the subjects approached in the remote way, the acceptance of national language or of the English ones. All of the above factors being *intentional*, the quality aspects are named QUALITY of DESIGN.

There are other factors which influenced the quality of the remote laboratory. They are: hardware and software utilized for the remote experiment, knowledge level of the producers (teachers) and of the consumers (students), type of quality assurance system in use inside of the schools, assessment and evaluation rules applied for the student knowledge, etc.. This group of factors will determine QUALITY of CONFORMANCE, indicating how well the laboratory works (as product) conforms to the specifications required by each training system who intend to use the remote experiment network.

There is a considerable necessity of the clarifications about quality in the field of the remote laboratory network, many times above notions being often used without a clear distinction. Being a global system, the remote experiment network includes an unavoidable conflict between *quality of design*, which represents a local decision and *quality of conformance*, which is a global requirement. As a result, in the paper the authors want to propose the application of some statistics methods, to do the above distinction and to start new approach regarding quality assessment in the remote experiment network.

Keywords-component; quality of design; quality of conformance; remote experiment; sampling; null hypothesis; OC curve; F ratio;

I. INTRODUCTION

If we agree the idea to consider all of laboratory works from the remote experiment network as a products and the students as a consumers, then quality is becoming the basic consumer decision. As every consumer from the market, student feels that the products of certain universities are substantially better in quality than the others. In this situation it is possible to apply in the laboratory work selection, the statistical methodology used in the quality control from manufacturing process? During the search of the laboratory works, the student has two alternatives: to accept the opened laboratory work or to reject it for some reasons. Because the student do not have time to do his acceptance after opening all of the similar laboratory works, it means that he made acceptance and rejection using only a sample from the entire ***"lot"*** of laboratory works. Up to now, the above operations seems to be similarly with acceptance sampling from statistical quality control. Three peculiarly aspects must to be mentioned:

1. Acceptance sampling, like above, do not estimate the "lot" quality; it simply accepts or reject laboratory works using some subjective criteria;
2. Acceptance sampling do not provide any direct form of the quality control;
3. The most effective use of the acceptance sampling is an audit tool which, ensure the customer that the output of a design ***conforms*** to its requirements.

There are some differences in the acceptance sampling applied to the laboratory works contained in the remote network:

1. Middleware, which ensure sampling of "n" laboratory work at one trial, selected at random from the "lot", will not be able to characterize the entire "lot" quality, as in the manufacturing process;

2. The final acceptance number "c" of laboratory work used by the student after selection, does not represent the limit of the defective items in the sample, as in the manufacturing process. It has the significance that: "if "c" laboratory work fulfill student's requirements, than will exist other with similar quality in the "lot" so that the next decision of the student-client will be to take a second sample";
3. The second sample will not offer to the student the right to do a global decision regarding the quality of the laboratory works contained in the "lot". It is due the fact of the huge diversity of evaluation of the laboratory work content, produced by the large diversity of the cultural heritages involved in the network;
4. In the case of the manufacturing process, the random numbers "n" is generated by a computer. In the case of the remote experiment network, the sampling is random because the middleware accessed diverse sites of the laboratory works in dependence with the situation of the momentary Internet connection.

II. SAMPLING ANALYSE

In the case of a single sampling plan, if the number of the similarly laboratory works are "N", then the sample size is "n" and the acceptance number is "c". If the nonconforming laboratory works observed is "d" and d ≤ c, then the student has minimum two laboratory works of the good quality? It is the question, because the criteria accordingly with comparisons and selection are made, will be also random, in direct connection with the student prerequisite knowledge.

The measure of the acceptance sampling plan is the operating characteristic (OC) curve. This curve plots the probability of the "lot" acceptance versus the lot fraction with nonconformities. The probability of observing "d" nonconforming laboratory works is:

$$P\{d\} = f(d) = \frac{n!}{d! \cdot (n-d)!} \cdot p^d \cdot (1-p)^{n-d} \qquad (1)$$

The probability of acceptance is the same probability when d ≤ c or:

$$P_a = p\{d \le c\} = \sum_{d=0}^{c} \frac{n!}{d! \cdot (n-d)!} \cdot p^d \cdot (1-p)^{n-d} \qquad (2)$$

where: p is the fraction of the nonconforming laboratory works in the "lot".

For example, from 500 laboratory works referring at Ohm law, suppositional existed in the remote network, the random sampling gives n=50 and the acceptance number c=3. Considering the variation of the lot fraction nonconformities "p" with the values given in the table 1:

TABLE I.

p								
0,01	0,02	0,03	0,04	0,05	0,06	0,07	0,08	0,09

the OC curve of the single sampling action there is in accordance with the Fig. 1:

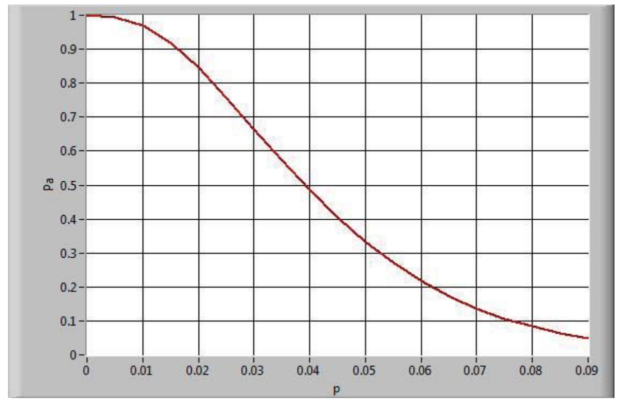

Figure 1. OC curve at single sampling action

As we have mentioned above, a warranty of the good selection impose a double sampling action. Obviously, a double sampling plan is defined by the four parameters:

- n_1, n_2 – sample size on the first sample respectively of the second sample;

- c_1, c_2 – acceptance number of the first respectively of the second sample with the condition $c_1 < c_2$;

The conditions which results from this action are:

- if $d_1 \le c_1$ the lot is accepted on the first sample;

- if $d_1 \ge c_2$ the lot is rejected on the first sample;

- if $c_1 < d_1 \le c_2$ a second random sample of size n_2 is drawn from the remote experiment network and the number of nonconformities d_2 are observed.

The combined number of observed nonconformities from both samples, $d_1 + d_2$, is used to determine the lot nonconformities:

- if $d_1 + d_2 \le c_2$ the lot is accepted;

- if $d_1 + d_2 > c_2$ the lot is rejected.

The OC curve for a double sampling activity has two curves. One P_{a1} for the n_1, c_1 and the second P_{a2} for the n_2, c_2 . P_{a1} , denotes the probability of acceptance of the first sample and P_{a2} the probability of acceptance of the second sample. P_a = P_{a1} + P_{a2} denotes the probability of acceptance on the combined samples. The calculation manner is mentioned in the following. First is calculated the P_{a_1} probability:

$$P_{a_1} = \sum_{d=0}^{c_1} \frac{n_1!}{d_1! \cdot (n_1 - d_1)!} \cdot p^{d_1} \cdot (1-p)^{n_1 - d_1} \quad (3)$$

with the condition: $d \le d_1 = c_1$

The second sample is drawn only if there is the condition: $c_1 < d_1 \le c_2$. The lot is accepted in the following situations:

a. $d_1 = c_1 + 1$ and $d_2 = 0$ or 1

That is, we find $c_1 + 1$ nonconformities on the first sample and zero or one on the second sample. The probability for this situation there is:

$$P\{d_1 = c_1 + 1, d_2 \le 1\} = P\{d_1 + c_1 + 1\} \cdot P\{d_2 \le 1\} =$$
$$= \frac{n_1!}{(c_1+1)! \cdot [n_1 - (c_1+1)]!} \cdot p^{c_1+1} \cdot (1-p)^{n_1 - (c_1+1)} \cdot \quad (4)$$
$$\cdot \sum_{d_2=0}^{1} \frac{n_2!}{d_2! \cdot (n_2 - d_2)!} \cdot p^{d_2} \cdot (1-p)^{n_2 - d_2}$$

b. $d_2 = c_2$ and $d_2 = 0$

That is, we find c_2 nonconformities on the first sample and zero nonconformities on the second sample. The probability of this is:

$$P\{d_1 = c_2, d_2 = 0\} = P\{d_1 = c_2\} \cdot P\{d_2 = 0\} =$$
$$\frac{n_1!}{c_2! \cdot (n_1 - c_2)!} \cdot p^{c_2} \cdot (1-p)^{n_1 - c_2} \cdot \quad (5)$$
$$\cdot \frac{n_2!}{0! \cdot (n_2 - 0)!} \cdot p^0 \cdot (1-p)^{n_2 - 0}$$

Thus, the probability of acceptance on the second sample is:

$$P_{a_2} = P\{d_1 = c_1 + 1, d_2 \le 1\} + P\{d_1 = c_2, d_2 = 0\} \quad (6)$$

For the entire lot, the probability of acceptance is therefore:

$$P_a = P_{a_1} + P_{a_2} \quad (7)$$

The OC curve fir the double sampling activity is shown in the Fig. 2.

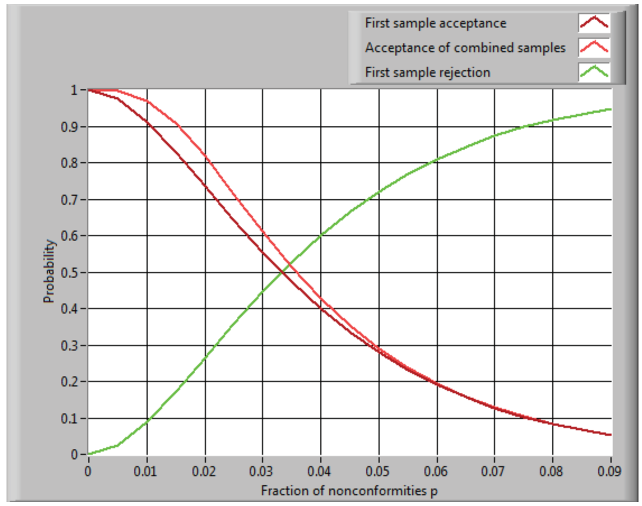

Figure 2. OC curves for the double sampling

Comments:

It is the first step of the quality analyze with statistic methods. It is referred at the quality of conformance because is a tool which indicates the manner in which the students accept or reject the laboratory works from the remote experiment network.

But, this action depends in a great measure by the some factors proper of the Internet environment:

- The number of the connections requested in the same time and the capacity of the remote site to accept one or more;
- The capacity of the middleware to do connections in conformance with the student solicitations;
- The speed of the Internet connection, used by the students;
- The student ability in the English language which determine the connection duration;

As a result, the quality analyze might be distorted. We have mentioned above that only sampling analyze will not give too much information about the laboratory works quality. It only gives us some indications about the quality of conformance. And the levels of the conformance there is distributed and diverse between users. We must introduce in the quality system of the remote network, in completion of the above tool, other analyze regarding quality of design [8].

III. KEPPEL METHOD

In our point of view, the good analyze of the quality of design applied at laboratory works is the method of null hypothesis applied by Keppel* in the behavioral sciences. We need a tool which allows us to state if the laboratory works opened by the students will produce effects on the student knowledge. The null hypothesis method evaluation gives us this certainty.

In short, for remembering the statistic assumptions regarding the null hypothesis, we have:

$H_0 : \mu_1 = \mu_2 = \mu_3 .... \mu_i -$ The null hypothesis;

$H_1 : \mu \neq \mu_1 -$ The alternative hypothesis;

The null hypothesis mentioned that we have the same values of the mean to the different populations analyzed. If H_0 is true, our treatments (learning from the remote network) do not give effects on the population.

The alternative hypothesis states that the values of the means are not equal. If H_1 is true, we expect to find some treatments effect with influence on the students knowledge.

The evaluation of the above situations is made through F distribution. Simply and direct, F ratio is defined as:

$$F = \frac{BETWEEN \quad GROUPS \quad VARIANCE}{WITHIN \quad GROUP \quad VARIANCE} \tag{8}$$

Between groups differences are the result of the combined effect of the experimental treatment and of the experimental errors. Within group differences represent the influence of experimental error alone.

F is a numerical index which is "sensitive" to the presence of treatments effects in the population. Only the value F > 1 indicate the existence of the treatment effect (see above definitions of the numerator and denominator of the F ratio).

We will present now the way and the motivations which will conduct us towards F ratio calculation and interpretation.

If we have an independent variable as factor A, with three levels of variation: a_1, a_2, a_3, applied at "s" subjects dawn form one population, the frequency distribution of the three sets of scores are presented in Fig. 3:

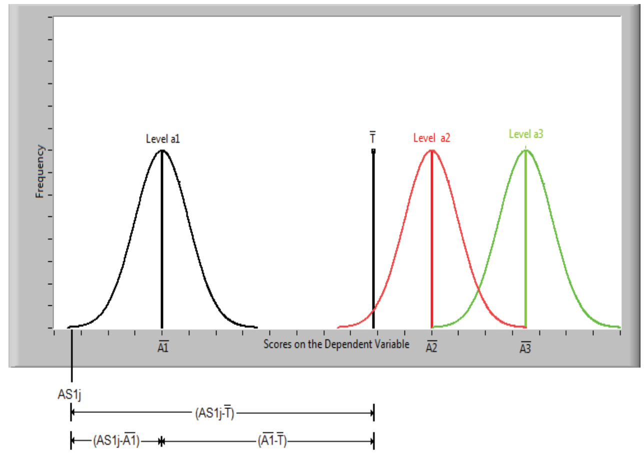

Figure 3. The components of deviation scores* [1]

According with the Fig. 3, AS_{1j} represents the scores at level factor "1" having "j" values, and the correlations showed are:

$$AS_{1j} - \overline{T} = \left(\overline{A_1} - \overline{T}\right) + \left(AS_{1j} - \overline{A_1}\right) \tag{9}$$

where: $AS_{1j} - \overline{T}$ - is total deviation;

$\left(\overline{A_1} - \overline{T}\right)$ - is between groups deviation;

$\left(AS_{1j} - \overline{A_1}\right)$ - is within group deviation

In the [1] this relation is written accordingly with the Hays [2] and Winer [3]:

$$SS_A = \sum_i^a s \cdot \left(\overline{A_i} - \overline{T}\right)^2 - \text{Between groups sum of squares;} \tag{10}$$

$$SS_{S/A} = \sum_{j=1}^{s} \left(AS_{ij} - \overline{A_i}\right)^2 - \text{Within group sum of squares;} \tag{11}$$

with the obvious correlation:

$$SS_T = SS_A + SS_{S/A} \tag{12}$$

Starting from these notions, we will calculate the F ratio. For this we need to have the "degree of freedom" df , which represents the number of scores with independent information which enter into the calculation of the sum of squares. Accordingly with the Keppel definition:

$$df = \begin{pmatrix} number \quad of \\ independent \\ observations \end{pmatrix} - \begin{pmatrix} number \quad of \\ population \\ estimates \end{pmatrix}; \tag{13}$$

* *we will use the same notations as Keppel*

For SS_A, $df_A = a-1$ and for $SS_{S/A}$, $df_{S/A} = a\cdot(s-1)$

As a result:

$$df_T = df_A + df_{S/A} = a-1+a\cdot(s-1) = as-1\,; \qquad (14)$$

The next step of calculations is the mean of squares:

$$MS_A = \frac{SS_A}{df_A} \quad and \quad MS_{S/A} = \frac{SS_{S/A}}{df_{S/A}} \qquad (15)$$

Where: MS_A estimates the combined presence of treatment effects plus error variance and $MS_{S/A}$ independently by MS_A estimates error variance.

Finally, the F ratio becomes:

$$F = \frac{MS_A}{MS_{S/A}} = \frac{\frac{SS_A}{df_a}}{\frac{SS_{S/A}}{df_{S/A}}} = \frac{SS_A}{SS_{S/A}}\cdot\frac{df_{S/A}}{df_A} \qquad (16)$$

Numerical example

Suppose that we were interested in the effect in the comprehension of three different instructions referring at one laboratory work. One group are verified if they succeed to memorize the basic law settled at the laboratory work, a second similar group is asked to concentrate upon measurement units, and their influence upon experiment, and the third group will work free, without recommendations. All of groups will receive finally a test regarding the comprehension of the laboratory work as a whole. In the hypothetical example there are s=5 subjects who were randomly assigned to each of a=3 treatments conditions. It means that, the subjects connections with the remote network was randomly, so that they will encounter one of the above instructions. Using the Keppel notations, the AS_{ij} matrix applied at the above experiment has the aspect (tab.2):

TABLE II.

AS_{ij}	a_1	a_2	a_3
1	13	7	8
2	17	9	10
3	11	8	6
4	10	6	7
5	14	7	8
6	15	10	9
7	9	6	8
8	11	7	5
9	13	5	9
10	17	5	10
$\sum A_i$	130	70	80
$\overline{A_i}$	13	7	8
$\sum_j^s (AS_{ij})^2$	1760	531	664

With these data we may compute, following the above scheme, successively:

$$SS_A = \sum_i^a s\cdot\left(\overline{A_i}-\overline{T}\right)^2 = \frac{\sum(A_i)^2}{s} - \frac{\left(\overline{T}\right)^2}{a\cdot s} = 206{,}7$$

$$SS_{S/A} = \sum(AS_{ij})^2 - \frac{\sum(A_i)^2}{s} = 135$$

$$df_A = a-1 = 2$$

$$df_{S/A} = a\cdot(s-1) = 27$$

$$MS_A = \frac{SS_A}{df_A} = \frac{206{,}7}{2} = 103{,}35$$

$$MS_{S/A} = \frac{SS_{S/A}}{df_{S/A}} = \frac{135{,}35}{27} = 5$$

$$F = \frac{MS_A}{MS_{S/A}} = \frac{135{,}35}{5} = 20{,}67$$

Because $F > 1$ we put into discussion the correctness of the null hypothesis.

Comments

Remote experiment network there is similar with a large population from which teachers drew at random three sets of 10 scores for each level of factor A, with the final goal to assess the quality of the content (design) [6], [7].

Assuming that this operation there is made by a large number of teachers, from different places, each operation consisting of three groups of 10 scores with the final goal to compute the value of the F ratio (standard method imposed by the remote network administrator), it is possible to be constructed a graph relating F and frequency of occurrence. We are in two situations:

- Curve of sampling distribution of F, when the null hypothesis is true;
- Curve of sampling distribution of F', when the null hypothesis is false;

All of teachers involved in this assessment expect to find some treatment effects, as a result of the described experiment.

The problem is to decide if, calculated value of ratio F, came from the F distribution of from F' distribution.

In the Fig. 4 is shown the empirical (F) and theoretical (F') sampling distribution of F (2, 27) the F ratio computed in the above numerical example. The empirical F (2, 27) distribution was obtained supposing that $\overline{A_1} = \overline{A_2} = ... = \overline{A_i}$ =7 (H_0 = true). The theoretical distribution was obtaining supposing that $A_1 = 7, A_2 = 8, A_3 =$ 13. In the both distribution, $SS_A = 206{,}7$.

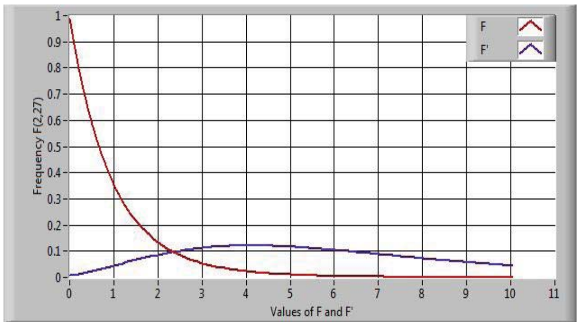

Figure 4 Sampling distribution of F and F'

The decision to reject of not the null hypothesis will be made by comparing the observed (computed) value of F with the value $F' = F$ located at the critical point of transition. The values of the critical F have been tabulated and, as we observed in the table 3, it is specified by three factors: $df_A(df_{numerator})$, $df_{S/A}(df_{denominator})$ and α , which is refers at the portion of the area to the right of an ordinate drawn at F_α .

The shortest explanation of α significance there is shown in the Fig. 5. As we observe, α define the region of incompatibility of the F distribution. It is in fact a probability called "*significance level"* and the investigator may pick any probability he wants. In the table 3 it is present a fragment of tabulated values for F at different α probabilities.

The decision to reject of not the null hypothesis is made by comparing the observed (calculated) values of F ratio with the value of F' ratio drawn from the above table consider: $df_{nom}; df_{denom}; \alpha$.

TABLE III. (FRAGMENT)

df_{denom}	df_{nom}							
	α	1	2	3	4	5	6	7
3	0,25	2.02	2.28	2.36	2.39	2.41	2.42	2.43
	0,10	5.54	5.46	5.39	5.34	5.31	5.28	5.27
	0,50	10.1	9.55	9.28	9.12	9.01	8.94	8.89
	0,025	17.4	16.0	15.4	15.1	14.9	14.7	14.6
	0,010	34.1	30.8	29.5	28.7	28.2	27.9	27.7
	0,001	167	148	141	137	135	133	132

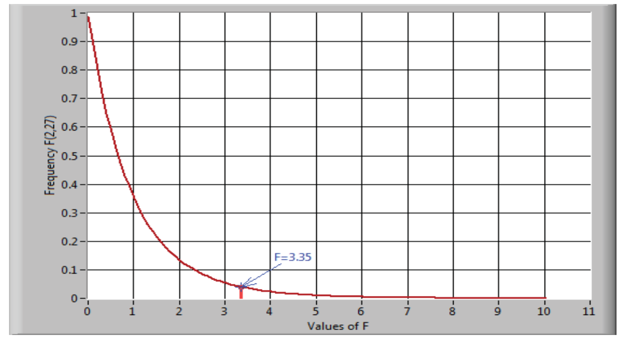

Figure 5 Sampling distribution of $F(2{,}27)$

With above clarifications we have the possibility to write the rule of decision:

- when $F_{calculated} \geq F_\alpha(d_{nom}, d_{denom})$ -reject null hypothesis H_0 . Otherwise do not reject H_0

In other words:

- If the value F - computed from experiment – falls within the region of incompatibility, the null hypothesis is rejected and alternative hypothesis is accepted;
- If the F value falls within region of compatibility, the null hypothesis is not rejected.

In our numerical example, df_{nom} = 2 and df_{denom} = 27. If we set α =0.05 the critical value of F (the value which share the F' distribution in incompatible and compatible regions) is 3.35 (from tables similarly with the table 3).

Because:

$$F_{observed} = 20{,}67 > F_{critical} = 3.35$$

we reject the null hypothesis H_0 , and we should conclude that treatment effects were present in this experiment. It means that, learning materials have some influence on the student knowledge. This conclusion means that the design of the laboratory work fulfill the quality requirements in some measure.

IV. CONCLUSIONS

It is possible to analyze the quality of the laboratory works existed in the remote experiment network with two methods:

- Quality of conformance with double sampling method;
- Quality of design with Keppel method;

The first method is useful in the case of the assessment of the laboratory work selection by the "clients" (i.e. students). Taking into account the number of the selections and the number of the rejections, it is possible to discuss about the quality of conformance. It isn't an absolute criterion regarding quality because of the fact that there are some outside limits which influenced the selection (Internet connection, Internet speed, language, middleware possibilities, etc.) with not direct dependence with the student opinion about the laboratory work utility.

In the second method, it is necessary to do some questionnaires, with real evaluation of the content, applied to a sampling from the entire population of the remote laboratory works having the same topics. The students will answer at these questionnaires, and using the proposed way, will be possibly to state if these laboratory works have some treatments effects on the student knowledge.

Because the problem of the quality in this environment is quite new, the present paper reflects the first preoccupations of the designers, both of the network and of the content, regarding quality assessment [5]. Sure, the development of this environment will increase these preoccupations and other quality evaluation method will be proposed. The most important thing is the fact that this problem of the quality is raise from the beginning of the development of this remote network [9], [10].

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Introducing alternative assessment into engineering language education at the Technical University of Madrid

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Abstract— **Engineering Institutions across Europe are currently involved in a major process of reform and restructuring as part of the Bologna Process, which stresses the role of competencies and outcomes in curriculum design. In the field of languages, the Council of Europe has developed the Common European Framework of References for Languages (CEFR), which aims to provide a reference framework for describing different qualifications, identifying different language learning objectives and setting out the basis of different achievement standards. Using this framework of language competence levels, our research group, over a three year period, has developed and piloted the Academic and Professional English Language Portfolio (ACPEL) especially designed for Engineering students and professionals. This portfolio was accredited by Language division of the Council of Europe in 2008. This paper will report on an ongoing project dealing with self and peer assessment based on the ACPEL portfolio. The project's aim is threefold: first, to train university language professionals in the use of self and peer assessment through the implementation of the ACPEL portfolio; secondly, to gradually introduce these assessment processes into the engineering language curriculum and finally to monitor and evaluate these two processes at the seven engineering schools.**

Keywords-assessment, higher education, second language, self assessment

I. INTRODUCTION

Actively involving students in their own learning and focusing on how to teach students to become more independent learners is a major educational goal in most European countries. The preamble of the Declaration of Barcelona on sustainability on Engineering education [1] asks us as engineering educators to address the whole educational process in a more holistic way implementing an integrated approach to teaching knowledge, attitudes, skills and values which incorporate disciplines of the social sciences and humanities. It also emphasises the need to promote multidisciplinary teamwork, creativity and critical thinking as well as to promote reflection and self-learning. Rompelman [2] argues that as engineering curricula are shifting from traditional teacher-oriented, individual programs toward learning oriented programs aimed at cooperation between students , not only is the role of the student changing but the role of the professor as well. Referring to this 'academic culture' of teaching, especially in tertiary education, Rogers [3] commented the following:

> When we put together in one scheme such elements as prescribed curriculum, similar assignments for all students, lecturing as almost the only mode of instruction, standard tests by which all students are externally evaluated and instructor chosen grades as the measure of learning, then we can almost guarantee that meaningful learning will be at an absolute minimum (p 21).

Since meaningful learning is a goal, emphasis should be on a student centred approach where learning is viewed both as a product and as a process. The acquisition of knowledge is then under the student's control. This implies that students should be actively involved in the planning and management of their own learning and take more responsibility for it as they progressively develop as independent learners. Teaching, learning and assessment practices are considered inseparable; and students should be active participants in the development of assessment procedures. Both the process and product of assessment tasks should be evaluated. Consequently, the assessment results should be reported as a qualitative profile rather than as a single score [4]. Hence the actual situation at our university with an intensive exam period and an overload of exams do not stimulate involvement in classroom sessions nor retention of course material [5].

II. SELF ASSESSMENT: WHAT IT IS AND WHY USE IT

Assessment in general is regarded as a process of collecting, synthesizing and interpreting information in order to

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make decisions on student performances. Assessment can be conducted to diagnose student problems to judge their academic performance, to provide feedback to students and to plan future learning. Self assessment in the educational context involves the learners in a process of evaluation and monitoring their own level of knowledge, performance and understanding. Enabling students to self-monitor their learning helps the students to develop knowledge through conscious control over that knowledge or to develop metacognitive awareness of knowledge and thought [6]. In a student-centred learning environment, this kind of assessment aims at preparing students to be autonomous, critical and responsible graduates and lifelong learners as promoted in the Bologna declaration.

Traditional assessment practices according to Boud and Falchikov [7] can undermine students' capacities to judge their own work. Students have to learn not to over rely on the opinion of others since in a working situation, these future engineers must be able to judge or evaluate the adequacy, completeness or appropriateness of their own outcomes. Hence, allowing self assessment opportunities that provide the learner with increasing responsibility helps them to be prepared for lifelong learning and assessment of this learning. Self-assessment plays an important role in helping the student extract meaning from the new experience and also helps him or her to reach an optimal level of performance. Practice in self-assessment helps students reflect on their own performance using relevant criteria and analyze strengths and weaknesses, becoming more critical toward their own role in outcomes.

III. Factors Affecting Self Assessment

Much of the literature on student self assessment has over emphasised the agreement of self awarded ratings and ratings awarded by the professor overlooking the value of self assessment as a learning tool. Orsmond, Merry and Reiling, [8] stress the importance of student development during all stages of the assessment process and Tan [9] argues that in classroom practice, professor-student mark agreement should be de-emphasised, and research should concentrate on the process and its outcomes that are experienced by the academics and their students.

In an extensive survey of research studies [10] on the impact of self and peer assessment in secondary schools, the following factors were found to have an impact.

- teacher attitude
- weaning away from dependence on other opinions, teachers included
- student involvement in criteria setting.

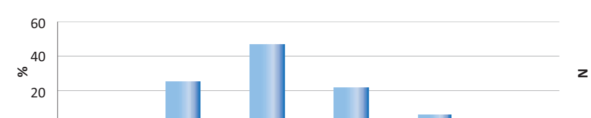
The professor, in this new paradigm, needs to be committed to learners having control over the process, and to be able to discuss learning and develop effective feedback. Also, it was found that this alternative assessment types have a larger impact on student outcomes when there is a move from a dependant towards an interdependent relationship between teacher and students. Finally, in situations where the students become "co-designers" of the criteria for evaluation, it seems to help them develop a better understanding of their own strengths and weaknesses. Oscarson [11] mentions six advantages of using self-assessment

- promotion of learning
- raised level of awareness,
- improved goal orientation,
- expansion of range of assessment,
- shared assessment burden
- and beneficial post-course effects.

Blue [12] identifies benefits such as encouraging greater effort, boosting self -confidence and facilitating awareness of distinctions between competence and performance as well as self awareness of learning strengths and weaknesses. Being motivated by the advantages of implementing self assessment, our research group has set up an ongoing project which intends to implement this assessment process.

IV. The Context

With an expected increase in workforce mobility, the need for engineers and architects to acquire communicative language skills is paramount [13]. These skills include not only formal linguistic goals such as improved pronunciation, better command of vocabulary etc. but also social and cultural language skills, as well as the ability to use different compensatory communicative strategies (like paraphrasing) when linguistic means are inadequate. Students are arriving at the university with varied levels of English language achievement. The European language reference framework (CEFR) [14] divides language achievement into 6 levels; A1 level is the most basic level and C2 the most advanced being equivalent to a bilingual capacity. A total of 232 from the schools of Architecture, Technical Architecture, Technical Aeronautical Engineering, Agricultural Engineering, Civil Engineering, Technical Mining Engineering, and Mining took the placement exam. Fig. 1 shows total distribution for level according to the CEFR.



	A1	A2	B1	B2	C1	C2
%	1	25	47	22	5	1
N	2	59	110	50	11	2

Figure 1. Percentage results of Oxford placement test

If we assume that the total levels are representative of the student body a near 77% are below the B2 level. The Chancellor of the university and his team have decided that all engineering and architecture graduates of the Technical University of Madrid must have at least a B2 level upon leaving the university. This requirement has been put into place in view of the European Space of Higher Education for student mobility and future job requirements. Hence it is paramount that the teaching staff and the students make an effort to improve their communication skills in English. Much work needs to be done with 73% of the student body falling below the B2 level..

The research group consisting of Technical English teaching staff and researchers from the above mentioned schools are making an attempt to move towards this goal. The wide range of teaching content areas included in the research group motivated us to develop a language portfolio which includes competence descriptors, i.e. learning outcomes covering all skills, which serve as criteria for the different genres taught. These learning outcomes will be used in curriculum design and for defining specific course objectives. The Academic and Professional English Language Portfolio (ACPEL) portfolio serves two major assessment purposes. The detailed list of language competencies can be used for student self assessment, to guide them through their learning process, to identify and set goals and to assess their learning progressively, inside and outside the educational framework, thus promoting self directed learning

A second rationale for developing the portfolio was to provide an interface between language learning, teaching and assessment. Learning outcomes can be a pedagogical resource for professors to determine the key purposes of the course and a practical tool for students to take control of their learning processes under the professor's guidance. Students do not become self-directed learners instantaneously; rather they need opportunities as well as clear directions and careful planning in many instances. The development process underwent several stages. Existing curricular programmes throughout the different schools of engineering and architecture were analyzed to determine the genres (both academic and professional) and criteria were set up for skill areas as well as genres. Five sets of 50 to 85 specific learning outcomes were developed and researched with the students for clarity and calibration, corresponding to the five categories: spoken production and interaction; written production and interaction; reception-spoken; reception-written; and working with oral and written texts [15] [16] [17]. After three years of development, piloting

TABLE I. SELF ASSESSMENT GRID (ADAPTED [14]

SKILL	B1* LEVEL OF REFERENCE	B2* LEVEL OF REFERENCE	C1* LEVEL OF REFERENCE
SPOKEN PRODUCTION AND INTERACTION	1 can connect phrases in a simple way in order to describe experiences and events. 1 can orally summarize a short experiment or a simple article in my field.	I can present clear, detailed descriptions on a wide range of subjects related to my field of interest. I can explain a viewpoint on a topical issue giving the advantages and disadvantages of various options.	I can present clear, detailed descriptions of complex subjects integrating sub-themes, developing particular points and rounding off with an appropriate conclusion.
WRITTEN PRODUCTION AND INTERACTION	1 can write simple connected text on topics which are familiar or of personal interest. 1 can write personal letters describing experiences and impressions. I can write brief reports of experiments and summarize articles.	I can write clear, detailed text on a wide range of subjects related to my interests. I can write an essay or report, in support of or against a particular point of view, and write letters highlighting the personal significance of events and experiences.	I can write clear, well structured text, expressing points of view at some length. I can write about complex subjects in a letter, an essay or a report. I can select style appropriate to the reader in mind.
RECEPTION / SPOKEN	1 can understand the main points of clear standard speech on familiar matters regularly encountered in work, school, leisure, etc. 1 can understand the main point of lectures or current affairs when the delivery is relatively slow and clear.	I can understand extended speech and lectures and follow even complex lines of argument provided the topic is reasonably familiar. I can understand most TV news and current affairs programmes, the majority of films in standard dialect.	I can understand extended speech even when it is not clearly structured and when relationships are only implied and not signalled explicitly. I can understand TV programmes and films without too much effort.
RECEPTION / WRITTEN	1 can understand texts that consist mainly of high frequency everyday or job-related language. 1 can understand articles in my field.	I can read articles and reports concerned with contemporary problems in which the writers adopt particular attitudes or viewpoints. I can understand contemporary prose.	I can understand long and complex factual texts, appreciating distinctions of style. I can understand specialised articles and longer technical instructions, even when they do not relate to my field.

and testing, writing and rewriting, the Academic and Professional English Language Portfolio (ACPEL)[18] was validated by the Council of Europe. The goal of this current study is to train students as well as academics in the area of alternative assessment procedures especially self assessment using the criteria set out in the portfolio.

V. THE PROJECT

The overall question to be addressed is "How does the implementation of peer and self assessment impact on students and academics in engineering education at the Technical University of Madrid?" In order to compare the impact of the implementation of self and peer assessment, the current assessment and evaluation procedures needed to be analyzed. To acquire this information, two procedures were carried out.

First, at the end of academic year 2008-2009 students were asked to fill out a questionnaire on their impressions of the different aspects of the course and professors wrote a report on methodology and evaluation procedures used up to this point. Table 2 shows types of evaluation used in the different schools. There seems to be a strong correlation between the number of students in the course and the number of different types of evaluation procedures. Small classes need fewer evaluation procedures, though more holistic (e.g. an oral presentation), while larger classes depend on more types of evaluation, (shorter and more frequent).

As to the student reactions to the course and the evaluation procedures, the results were important so as to get a profile of the students and the course content in the different schools. Various blocks of evaluation were included in the questionnaire: genres taught in the course (8 types), learning activities, assessment method, hours dedicated to the course, satisfaction and global learning competences.

TABLE II. MOST VALUED GENRES FOR EACH COURSE

Genres and competences	Tech. Mining	Tech. Aeron	Tech, Agric	Mining	Agricul	Civil	Architec
oral presentations	3	3					
reading skills	2	2	1	2		1	
summary writing			2	1		2	3
report writing	1		3	3	2		
Curriculum vitae					3		1
letter writing					1		2
e-mail composition		1				3	

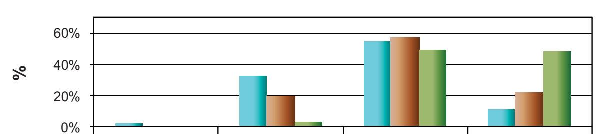
We shall concentrate here on the students' evaluations of the genres, global learning and satisfaction. The eight genres included in the questionnaire were the following: oral presentations, research skills in internet, reading skills, summary writing, report writing, curriculum vitae, letter writing, and e-mail composition.

Table II demonstrates the results of the student evaluations for the genres and competences included in the questionnaire. The students were asked to evaluate their learning in following genres and competences on a 5 level Likert scale from "very low" to "very high". The three most valued for each course/school are included with 1 depicting the most valued. These results have set the basis for the course assignments that are being included in the self and peer assessment.

TABLE III. ASSESSMENT AND EVALUATION PROCEDURES

	Tech. Mining	Tech. Aeron	Tech. Agric	Mining	Agricul	Civil	Architec
oral presentation	x	x					
attendance & participation	x	x	x	x	x		
project work		x	x		x	x	x
exercises							x
final exam	x		x	x			x
continuous evaluation	x		x	x		x	
periodic quizzes	x			x		x	

Other information important to the study was also gathered in the questionnaire. The students were asked to evaluate how satisfied they were about their language learning from "very low" to "very high". Another question posed to the students was "How do you evaluate the amount of learning in the course?". Finally, we asked to students to appraise the amount of information supplied to them about the grading and evaluation system utilized by the professor in the course. None of the students choose "very low" on any of questions hence this alternative has been removed from the graph for more clarity. Fig. 2 shows that the level of satisfaction of the students learning to be quite high with nearly 80 percent marking "high" or "very high". We can see that their opinion of the amount of learning is high but substantially less than satisfaction about their language learning. A surprising 97 % of the students considered the amount of information to on the methods of evaluation "high" or "very high".



	low	average	high	very high
Satisfaction	2%	32%	55%	11%
Learning	1%	20%	57%	22%
Evaluation	0%	3%	49%	48%

Figure 2. Results of student questionnaire

VI. THE ONGOING PROJECT

Well designed self-assessment procedures that present students with explicit criteria, that provide for student involvement in assessment decision-making, that elicit student opinions about their performance, that base student goal setting on achievable targets, are the keys for enhancing student learning. Fig. 3 highlights the processes involved in self and peer assessment and how it affects student performance. One can see that the learner is at the centre of the assessment and the learning process being affected by many factors. Goals, effort, performance, self-judgment, and self-reaction all can combine to impact self-confidence in a positive way. However, a negative cycle can develop if there are significant gaps between the different factors and learners tend to perceive themselves as unsuccessful performers. Professors must be involved in the process of training students to assess effectively. The goals of our ongoing research and the practical model and ideas that follow are aimed at assisting professors with this important work.

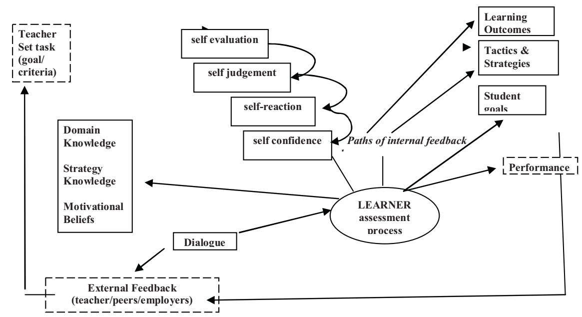


Figure 3. Process of learning through assessment

The procedures being followed by the members of the project are numerous. Once the professors were informed and trained in a 4 hour workshop, each professor has involved their students in defining the criteria that will be used to assess their work with the help of the learning outcomes descriptors from the portfolio. Table IV is a small selection of can do language descriptors currently being used for self and peer assessment in the Technical school of Aeronautical Engineering. In addition to increasing student commitment to instructional goals, negotiating criteria and learning outcomes enables professors to help students set goals that are specific, immediate, and moderately difficult, characteristics that contribute to greater learning.

TABLE IV. SELECTION OF CAN DO STATEMENTS

A2	Can give a short, rehearsed presentation on a familiar academic or professional topic, being aware of the use of body language to transmit information.
B1	can structure a simple talk in a comprehensible way, indicating the beginning and end of each section, using cohesive devices and present it clearly, speaking from notes or visual aids (e.g. outlines, diagrams, charts, etc.)
B2	Can give a clear, prepared presentation, discussing the advantages and disadvantages of various options or solutions to a problem, using cautious language and modality.
C1	Can attract the attention of the audience using appropriate presentation strategies e.g. intonational clues, voice volume, etc.

Once the criteria have been established, students can then apply the criteria to the examples of the genres dealt with in the course. These models or examples help students understand specifically what the criteria mean. Templates can also be used to provide lower level students with guidelines for improving their learning cycle. Once the criteria are clear the students develop an assignment and apply the criteria to their own work. The next step in the process is to apply the criteria to peer work. This can be done in a cooperative learning environment, such as group work. At this point, the professors will provide feedback on the self and peer evaluations. Discussion regarding differences can follow and perhaps adjustments are needed. An important part of the process can be the support provided to the students in setting up their goals and developing strategies to achieve them.

VII. CONCLUSIONS

Self assessment is a process where students are involved in and are responsible for assessing their own piece of work. It encourages students to become independent learners and can increase their motivation. Peer assessment is where students are involved in the assessment of the work of other students. Research evidence, outside of the field of language learning, report that students experience increased self -esteem, increased engagement with learning, especially goal setting, clarifying objectives, taking responsibility for learning, and/or increased confidence. Assessment is acknowledged as a major influence on student learning. Thus, all assessment activities need to be examined from the point of the view of what they contribute to prompting student learning which should be the intended outcome from the course. Assessment needs to be demystified to allow students to become confident enough to use it as well as make connections between assessment activities and learning. Since students will inevitable have to make their own assessments in the real world, ample opportunities should be offered to practice this skill.

ACKNOWLEDGMENT

The authors thank all the teaching staff participating in this study for their dedication both to the project and to innovative assessment procedures.

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Session 09E OCW-Universia Special Session: OCW and Open Educational Resources

OCW Consortium: learning through the worldwide sharing and use of free, open, high-quality education materials organized as courses

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Role of regional consortia in OCWC: OCW-Universia

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Development of the OCW Consortium

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MIT OpenCourseWare - OpenCourseWare Consortium

OCW Consortium: learning through the worldwide sharing and use of free, open, high-quality education materials organized as courses

Special Session

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Abstract— **A special session is proposed to present the current status of OpenCourseWare Consortium from different viewpoints: from the OCWC Board of Directors's view, UNIVERSIA as leader of a regional OCW consortium, and best practices of other universities.**

Keywords: open educational resources, ocw

I. Introduction

Global educational systems are unable to meet current needs. Systems of primary, secondary and higher education around the world are struggling to find the resources and trained educators required to meet the demands for education and certification, particularly in the face of rapid population growth and economic development. The current global economic crisis exacerbates these problems through the creation of a displaced labor force in need of retraining at a time when resources supporting educational systems are further diminished.

Technology is an increasingly disruptive force on educational systems, both positively and negatively. The Open Educational Resources (OER) movement is a trend toward the creation of openly-licensed resources including open references such as Wikipedia, open access journals, open educational technologies, open text books, open data sets, open learning object repositories, shared resources such as iLabs and many others. Open educational resources are proliferating in type and number. There is a rapidly increasing number of open educational resources attracting ever-higher levels of use. As of yet, few synergies have emerged between these related but separate undertakings, and as a whole the movement often provides a confusingly kaleidoscopic array of resources and opportunities. The progress and promise of OER, however, both remain substantial. Open educational resource creation and use is becoming a widespread global best practice. The spread of OpenCourseWare publication, open access publication, as well as the use and integration of OER into new materials, are all increasing. Forums such as the UNESCO-OER mailing list are bringing together a global OER community.

The OpenCourseWare (OCW) project, as part of the OER movement, started at the Massachusetts Institute of Technology (MIT), in the year 2001, with the aim of offering pedagogical materials in an open and free of charge basis to society. The mission of the OpenCourseWare Consortium is to advance formal and informal learning through the worldwide sharing and use of free, open, high-quality education materials organized as courses. An OpenCourseWare (OCW) is a free and open digital publication of high quality university-level educational materials – often including syllabi, lecture notes, assignments, and exams – organized as courses. This philosophy is being spread to the world main universities creating the OCW Consortium (OCWC), in which more than 250 universities and associated organizations worldwide committed to advancing OpenCourseWare sharing and its impact on global educational opportunity. The OpenCourseWare Consortium (OCWC) has been formed [4] with the proposal of expanding the reach and impact of opencourseware by encouraging the adoption and adaptation of open educational materials around the world.

II. Focus Areas

Papers of this special session will highlight some of the work related with OCW movement with representation in the following areas:

- The OpenCourseWare Consortium (OCWC) is undergoing a period of rapid growth and organizational development. The number of participating institutions, live OCW sites, and total available courses are all increasing rapidly. The Consortium is straining to develop the organizational structures needed to accommodate this growth. The OpenCourseWare Consortium is just developing as an organization. We will count on the representation of the OCWC Board of Directors of the OCWC to explain how the Consortium faces the dual challenges of developing initiatives to support Consortium goals and developing the systems and infrastructures needed to operate the organization.

- Subconsortia are emerging in increasing numbers around the world. Regional groupings of OpenCourseWare projects are emerging around the globe, bringing large groups of universities into the OpenCourseWare Consortium. UNIVERSIA, one of the greater networks of university cooperation, which merges 1,070 universities and higher education institutions in 11 countries of Latin America, leads the OCW UNIVERSIA and tries, under the cultural and geographic affinity of the Latin American space, to facilitate the presence of the institutions of higher education of this region in the world-wide OCWC and to promote the open publication of its courses and others educational contents in the languages of our community. The OCW Universia view for our current situation will be presented in this session.
- The consortium helps you create content—more effectively and more efficiently—by providing an environment for the sharing of best practices among our members. Some of these practices developed by other technical insitutions will be presented.

Development of the OCW Consortium

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Abstract—**This paper documents the development of the OpenCourseWare Consortium, from the origins of the OCW concept at MIT and that Institute's early commitment to supporting other adopters of the model, to the rapid growth of the community in the period 2004-2007, to the Consortium's incorporation as an independent entity and current activities and status.**

Keywords-OpenCourseWare; open educational resources

I. A NEW MODEL FOR OPEN SHARING

In the year 2000, an MIT faculty committee on lifelong learning made a proposal that was as simple as it was revolutionary. The committee was charged with recommending a strategy for MIT in confronting the growing impact of the Internet on higher education, and in particular, in confronting the emerging field of digitally supported distance learning. After surveying the online education landscape, they saw that distance learning was both difficult to provide profitably and at some level fundamentally at odds with the Institute's mission to disseminate knowledge. Online education—as it was conceived at the beginning of the century—would take the academic riches of the Institute and lock them behind a firewall for only those who could pay.

Instead, the committee proposed, why not use the Internet to give away the academic content at use in MIT's classes? Rather than trying to create entire new programs specifically designed for online delivery, why not take the core academic documents already created at the Institute—the syllabi, lecture notes, assignments and exams handed out in MIT classrooms—and make them widely and freely available on the World Wide Web? Instead of pursuing profit, as was the prevailing model, the committee suggested the goal should be generating global benefits through a philanthropic approach. They further proposed that MIT should share materials not from a select few courses, or from the subjects for which the Institute was best known, but from the entire MIT curriculum, undergraduate and graduate.

In sharing these materials, the committee hoped to provide educators around the world resources they could build upon in creating materials for their own classrooms. They also hoped to provide students everywhere with access to additional resources to supplement the materials they received in their classes. Independent learners, too, might benefit from accessing theses materials to learn for pleasure or to solve professional problems. Rather than online instruction, the committee hoped to provide open resources that would benefit the widest possible population and change the overwhelmingly commercial direction of online higher education.

As sweeping as this vision was, the faculty had a more ambitious idea. They recognized that if MIT undertook such a program, it might provide benefit to hundreds of thousands, maybe millions, but the concept—which they dubbed OpenCourseWare (OCW)—would not fundamentally change education unless it was widely adopted by universities around the world. As they sought funding to start the program, which was quickly provided by the William and Flora Hewlett and Andrew W. Mellon foundations, they proposed that in addition to publishing all of MIT's educational materials, the team assembled would also provide advice and assistance to other schools seeking to publish their materials openly.

It was this commitment that would, in five short years, result in an independent organization with a globally distributed staff that serves the needs of more than 200 universities and affiliates—the OpenCourseWare Consortium.

II. A SHARED MISSION

While the MIT team had been tasked with helping other universities with adopting the OpenCourseWare model, they fully expected it would take several years to prove the effectiveness of the model before OpenCourseWare began to see widespread adoption. The mission of sharing educational materials openly and freely, however, was itself far more resonant that anyone at MIT had expected.

Almost as soon the MIT OpenCourseWare site was launched in 2003—with no advance contact—another OpenCourseWare site appeared on the Web. The Fulbright Economics Teaching Program OpenCourseWare site (http://ocw.fetp.edu.vn/home.cfm) launched in the fall of 2003 as well, with the following reference to MIT's program on the home page:

> *Inspired by the Massachusetts Institute of Technology's OpenCourseWare Initiative (OCW), the Fulbright School has begun to publish its teaching and research materials online. FETP OpenCourseWare is not a long distance learning project, rather it is a resource for people working or studying in policy-related fields to increase their knowledge and explore new approaches to learning and curriculum development.*

Beginning in early 2004, before evaluation of the early stages of MIT's program had been published, MIT began to receive inquiries and invitations to speak from universities in the United States and around the world. During 2004 and into 2005, the MIT OpenCourseWare team spoke with leading universities in Japan and in France, as well as US schools including Johns Hopkins, Notre Dame, Tufts and Utah State University.

The common thread connecting all of this communication was a commitment to the mission of openly sharing educational materials. Tufts University already maintained extensive international partnerships, and OCW was seen as a natural extension of these commitments. Johns Hopkins Bloomberg School of Public Health saw OCW as a powerful new tool they could employ in the service of global health. For Utah State University, OCW enhanced the school's ability to serve the residents of Utah. Notre Dame saw OCW as a way to give global visibility to their specialty in ethics. Even before MIT had solid proof of OCW's effectiveness, these schools were planning OCW programs of their own.

Schools outside the United States demonstrated an equally enthusiastic response to the mission. In 2004, MIT linguistics professor Shigeru Miyagawa, a member of the original faculty committee on lifelong learning, was invited to speak about OpenCourseWare with the presidents of leading Japanese universities. In the span of a few months, this series of meetings would result in the launch of the Japan OCW Consortium (http://www.jocw.jp/), a collaboration of nine top Japanese universities. In early 2005, the MIT OpenCourseWare staff was also contacted by representatives of a group of top French engineering schools, ParisTech, who were interested in launching their own OpenCourseWare initiative. This contact would ultimately bear fruit in the launch of the ParisTech "Graduate School" site (http://graduateschool.paristech.fr/?langue=EN).

III. From Community to Consortium

During 2004 and early 2005, MIT struggled to keep up with this early and unexpected interest in the OpenCourseWare model. MIT's site had received over 4 million visits in its first year, and evidence was quickly being collected demonstrating the effectiveness of the model. This attracted the attention of an even wider group of interested universities around the world, each with its own set of questions about how they might implement an OpenCourseWare site.

In March 2004, the MIT staff produced and launched a "How To" site, providing thousands of pages of documentation detailing MIT's implementation approach for OCW—a resource that would receive more than 23,000 visits before it was finally archived in March 2009. But the MIT staff quickly discovered that these new projects joining the nascent movement often had better advice to offer one another than MIT did.

The MIT program had been implemented at a scale and with a budget far beyond those of the other programs, and MIT's solutions were often a misfit. The MIT staff shifted gears from providing direct advice to facilitating communication between emerging OCW programs. A clear cluster of issues emerged as key challenges to this group of early adopters, including faculty recruitment, technology choices, intellectual property management, and sustainability. As the new programs began implementation, each began to provide leadership in these areas.

Utah State University sent a team of technologists to examine the MIT's technical infrastructure and created a scaled-down open source content management system appropriate to the needs of the emerging OCWs, a system since adopted by scores of other programs. Notre Dame and the schools of the Japan OCW Consortium introduced innovations in the management of intellectual property and licensing. Johns Hopkins developed a unique approach to image management. Tufts University distributed their OCW staff across existing units at the school, embedding the costs of site production across numerous budgets and enhancing program sustainability. The challenge for MIT became how to capture this burst of innovation and share it back with the rest of the community.

The early adopters of the OCW model were joined in 2004 by energetic organizations that began translating OCW materials produced by MIT and others. Universia.net, an IberoAmerican educational portal supported by Banco Santander, began translations of MIT courses into Spanish and Portuguese. The American-based IET Foundation, led by Dr. Fun-Den Wang, established China Open Resources for Education (CORE), an organization tasked with translating course materials from many of the early OCWs into simplified Chinese. These efforts, funded by the translating organizations themselves, were important in bringing OCW to a wider global audience.

By early 2005, it was clear that the MIT staff could not facilitate the volume of discussion generated by the sharing of publishing innovations and coordination with translation partners. A structure was required in order to support more direct exchange of ideas and information. On February 17, 2005, a meeting was held on the MIT campus that brought together representatives of China Open Resources for Education, Japan OCW Consortium, Johns Hopkins Bloomberg School of Public Health, Tufts University, Universia, University of Notre Dame, Utah State University and MIT. At this meeting, the participants agreed the time had come to form an organization to support the production and use of OpenCourseWare materials.

IV. Early Development of the Consortium

At the meeting on MIT's campus in early 2005, participants agreed to hold the first meeting of the OCW Consortium in conjunction with Utah State University's OpenEd conference planned for that fall in Logan Utah. But even this decision created challenges, as the Consortium was not a legal entity and had no staff or budget. As the program with the largest staff and budget, MIT stepped forward to manage the planning of the meeting, and the Hewlett Foundation provided a small line item in MIT's grant to support the Consortium.

At that first formal gathering of the young organization, the members articulated a mission for the organization, "to advance education and empower people worldwide through

OpenCourseWare.” The group further defined a set of goals in support of that mission and decided to create a portal Web site that linked all of the member OpenCourseWare sites and shared best practices to encourage more schools to join. Finally, the members agreed to meet again April 2006 on the campus of Kyoto University.

In collaboration with Kyoto University staff, MIT staff once again supported the planning and execution of the April 2006 meeting, which saw the launch of the OCW Consortium portal (http://ocwconsortium.org). Through 2006, participation in the Consortium continued to grow, with new projects emerging in regions including the United Kingdom, China and Taiwan, Vietnam, South Africa and Venezuela. In all some 70 universities and affiliated organizations were represented by the time the Consortium gathered again in Utah during OpenEd 2006.

MIT had reached the extent of its capacity to manage the Consortium, and the decision was made to hire a full-time executive director to support the activities of the group. The Consortium was still an informal organization, however, and so MIT hired a full-time employee on their OCW staff to serve the Consortium. This staff member catalyzed tremendous growth in global participation during the period 2006 through 2008, managing three additional meetings, overseeing the incorporation of the Consortium as an independent entity, and securing a three-year $1.5 million dollar grant from the Hewlett Foundation to support the organization.

V. Emergence of an Independent Consortium

During the Spring of 2008, in preparation for the formal incorporation if the Consortium, the members elected the organization’s first board of directors. The board met for the first time at the Consortium’s April 2008 meeting in Dalian, China, and included representatives from China, Japan, Korea, Mexico, the Netherlands, Spain, South Africa, the United Kingdom, and the United States. When the formal incorporation papers were signed July 9th, 2008, the Consortium was officially an independent organization under the direction of these community representatives.

In order to ensure the direction of the organization reflected the interests of the full community, the board undertook an organizational planning process in late 2008 and early 2009, resulting in the Consortium’s first formal strategic plan. This plan articulated the vision of this growing body of international universities and their affiliates:

> *We envision a world in which the desire to learn is fully met by the opportunity to do so anywhere in the world, where everyone, everywhere is able to access affordable, educationally and culturally appropriate opportunities to gain whatever knowledge or training they desire. The Consortium acts to realize this vision by addressing one issue—that of access to high-quality educational materials—and by partnering with organizations addressing related problems that must also be solved to make this vision a reality.*

The document also reexamined the previously articulated mission statement, declaring the purpose of the Consortium was “to advance formal and informal learning through the worldwide sharing and use of free, open, high-quality education materials organized as courses.” The document likewise refined the goals of the organization as follows:

1. *Increase the number of members in the OCWC, and the number and diversity of OpenCourseWare courses they make available;*
2. *Enhance the value of OCW courses to all types of users around the world; and to*
3. *Build and nurture a vibrant, culturally diverse global OpenCourseWare community that is connected to the broader OER movement.*

The strategic plan further identified a series of strategic initiatives in support of those goals that provided direction to the small staff..

VI. Serving Producers and Users of OCW

The Consortium today supports emerging OpenCourseWare projects, builds global awareness and use of OpenCourseWare materials, and connects the vibrant OCW community to the education, government and private sectors. More than 200 universities around the world participate in Consortium activities, and collectively they have published materials from an estimated 13,000 courses in more than 20 languages. Volunteers around the world have translated an additional 3,500 courses from their original language.

This vast collection of academic materials provides opportunities to individuals around the world for personal and professional development. It also supplies an infrastructure to governments, NGOs and educational institutions for use in addressing a diverse set of challenges including workforce development, educational system improvements, and public health enhancement. All OCW materials are available through the Consortium’s Web site (http://ocwconsortium.org), and the Consortium staff builds general awareness of OCW through media and outreach.

The OpenCourseWare Consortium has also clarified and diversified its categories of membership to make the organization as inclusive and sustainable as possible. Member categories now include:

- **Institutional members** – the accredited higher education institutions that make up the bulk of the membership and are the primary producers of course materials.
- **Associate consortia** – consortia of universities affiliated by region or common interest, such as the Japan OCW Consortium, which are important coordinating bodies in the community.
- **Associate institutional members** – accredited higher education institutions for which the primary connection is through an associate consortium, and which pay reduced dues and have reduced voting rights for board elections.

- **Affiliates** – organizations that are not accredited higher education institutions but nonetheless further the mission of the Consortium in one or more ways; includes standards groups like Creative Commons and NGOs like Fahamu publishing educational materials.
- **Corporate members** – corporations supporting the OpenCourseWare Consortium and providing services to other members.

In a very brief span of time, the OpenCourseWare Consortium has grown from of a common commitment to serving world educational needs through an innovative model into a global organization supporting a diverse community of OCW users and producers. The Consortium faces the significant challenge of transitioning from grant funding to sustainable sources of revenue including significant member support. To begin the transition, the Consortium introduced membership dues this year of between US$50 and $500 depending on membership category and member region. In a demonstration of commitment to the Consortium, a core group of leading universities and organizations, including most of those described throughout this paper, have each pledged US$5,000 per year in each of the next five years to the Consortium. This statement from across the community indicates the strength of the OCW movement and suggests Consortium will be supporting the production and use of OpenCourseWare materials for many years to come.

Session 09F VISIR Special Session: Workshop on VISIR electrical and electronic remote lab: Principles and educational view

Workshop on VISIR electrical and electronic remote lab: Principles and educational view

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Session 10A Area 1: Adaptive and Personalized Technology-Enhanced Learning

Indexing and Searching Learning Objects in a Peer-to-Peer Network
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Public Displays and Mobile Devices in an Augmented Objects Framework for Ubiquitous Learning
Madeira, Rui Neves
ESTSetúbal/IPS (Portugal)

Adaptation in a PoEML-based E-learning Platform
Anido-Rifón, Luis; Caeiro-Rodríguez, Manuel; Pérez-Rodríguez, Roberto
University of Vigo (Spain)

Madar learning : learning envirnment for E&M learning
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Indexing and Searching Learning Objects in a Peer-to-Peer Network

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***Abstract*—In this paper, we explore the idea of using Peer-to-Peer (P2P) networks as advanced educational tools. A P2P network can disseminate complex learning objects that act as anchors for creating collaborative learning communities. The goal is to create collaborative spaces of learners with similar interests to exchange knowledge, opinions, and experience so that they can learn, understand, and help/teach each other. The use of the P2P technology for disseminating learning objects requires extending current P2P systems with a support for precise indexing and searching. In this way, potential learners can easily find and choose relevant objects. The present paper describes the design of an indexing and searching scheme for disseminating complex mutable SCORM learning objects over BitTorrent.**

***Index Terms*—learning objects; peer-to-peer systems; indexing; DHT**

I. Introduction

In this paper, we explore an idea for future educational tools based on Peer-to-Peer (P2P) networks. Although such networks offer a wide-spread means for disseminating media content, currently they are mostly limited to music and movies. However, a P2P network may also provide easy access to educational resources instead of, or in addition to, standard publishing of course material on Web servers, which often requires considerable management and maintenance effort. In a similar way to video or music files, we can easily disseminate complex *learning objects* in a standard format such as SCORM [1] among interested learners. As P2P networks operate in an autonomous and spontaneous way with minimal management overhead, users can use P2P applications with little or no training.

We have begun to investigate how educational activities can benefit from P2P networks and how we need to enhance current P2P applications for disseminating learning objects. This goal requires addressing the problem of precise indexing and searching so that potential learners can easily find and choose relevant objects. Another idea to explore is to use learning objects as anchors for creating *collaborative learning communities*. Current P2P applications only disseminate content, but users are not aware of who downloads a given file. Knowing that somebody else is interested in a movie or a music file may lead to interesting user interactions such as following the choice of somebody else or establishing collaborative opinions and advices. If we can attach some information about users interested in specific content to files disseminated over P2P networks, we would enable creation of collaborative spaces of users with similar interests. Once such a social network starts, its members can exchange knowledge, opinions, and experience as well as they can extend their activities to learning processes by providing support, explanations, discussions, and even mutual teaching. One interesting feature of such a set up is that collaborative learning communities may enhance the existing content and add more resources to a given course material. Thus, we need to take into account that learning objects become mutable unlike files disseminated in current P2P networks.

The present paper describes the design of an indexing and searching scheme for disseminating complex mutable SCORM learning objects over BitTorrent [2]. Our approach takes advantage of attributes extracted from SCORM objects and of indexing concepts and terms added by the user from a domain ontology. We use OpenDHT [3], an open distributed storage service implemented over Planet Lab [4] to store all needed indexes and associations. We have implemented the proposed schemes in GLEN (Global Lecture Exchange Network), a prototype P2P client based on Azureus (Vuze) [5].

II. Design goals

Our goal is to disseminate learning objects in a P2P network in a way that enables creation of collaborative communities of learners. We recall below the design goals of our system:

- Support wide and easy distribution of learning objects. Extend existing P2P applications for sharing, searching, and downloading learning objects in a fully distributed way without a central server.
- Change the traditional hierarchical teaching model into a flat one in which anybody can teach anybody. Anybody can download any learning object, extend its content, or add a new learning object.
- Create collaborative communities of learners having common interest and objectives based on the access to the same learning objects.
- Use learning objects as anchors for easy interactive communication between learners (e.g. through Voice over IP (VoIP) applications such as Skype or Gizmo). Down-

loading a learning object gives information about other learners that share the same interests.

Based on this set of requirements we have developed several new schemes for structuring, indexing, and searching learning objects. We describe them below.

III. Structure of complex learning objects

We consider learning objects in the SCORM 1.2 format that allows linking various resources and adding descriptions in the LOM format [6]. Popular engines like Blackboard or Moodle can display such learning objects and several editors exist such as eXe [7].

A. BitTorrent and DHT

We have decided to use BitTorrent as the underlying P2P network and enhance a P2P client based on Azureus (Vuze) [5] to support advanced functions of indexing, searching, and retrieving learning objects. BitTorrent disseminates objects through a *torrent* file that contains the information on an object needed for downloading (name, piece length, number of pieces, tracker, etc.). A *tracker* is a HTTP server that keeps information on *peers*—nodes downloading the same object. There are two categories of peers: *seeders* that have already downloaded the whole object and can provide its pieces to *leechers*, the peers that have not yet obtained all the pieces.

To download an object, a peer first downloads a torrent file, computes the SHA1 hash function on its information part, and contacts the tracker to obtain seeders (their IP addresses and ports) that can send the pieces of the object. Then, it queries them to obtain a bitmap of pieces stored at each seeder and requests their download. A leecher also provides already downloaded pieces to other peers.

In the *trackerless* operation of BitTorrent, the information usually maintained by a tracker (peers, their addresses and ports) is stored in the DHT (Distributed Hash Table) organized on peers in a fully distributed way. Even if Azureus only uses the DHT for storing the information usually maintained by a tracker, we explain below the operational principles of the DHT, because we rely on such a distributed storage service for indexing and searching.

Azureus uses a modified Kademlia implementation for its DHT [8] to store $(key, value)$ pairs on different nodes. The DHT interface offers the following operations:

- $Ping$ to verify routes to other peers,
- $Lookup(key)$ to find nodes that are near to the key in the keyspace (nodes are identified by the SHA1 hash of the node IP/port combination),
- $Store(key, value)$ to store the $value$ on the nodes close to the key in the keyspace,
- $Get(key)$ to retrieve the $value$ from the nodes close to the key in the keyspace.

To explain the operation of the DHT, we take an example of storing files in the DHT (other P2P networks such as eDonkey or eMule for example use a DHT to store and retrieve files). A file is identified by a key derived from its filename—a key is a 20 byte SHA1 hash function on a filename: $key = h(filename)$. The DHT maps keys to nodes in the P2P network: the keyspace is the set of 20 byte strings and each node has its place in the keyspace. To store a file, a node first performs the $Lookup(key)$ operation to find nodes that are near to the key and then stores the file as the value of the $Store(key, value)$ operation at 20 nodes close to the key in the keyspace. Retrieving the file proceeds in the inverse way: a node looks up nodes close to a key and gets the file from one of the nodes.

When Azureus operates in the *trackerless* mode, it uses its DHT to only store the *torrent* information on *peers*, then downloading of pieces proceeds in parallel from a large number of peers. The key of the *torrent* information is a 20 byte SHA1 hash function on the descriptor (the information part of a torrent): $key = h(descriptor)$ and the stored value corresponds to the information on the seeders usually maintained by the tracker and necessary for downloading.

B. Learning objects and their structure

We want to design the structure of our learning objects so that they may evolve while they disseminate in a collaborative community: we want to be able to enhance the existing content and add more resources, which results in multiple versions of a learning object. However, existing P2P objects like an MP3 or a video file are immutable, i.e. they cannot be modified once published on a P2P network. Thus, we need to enhance the structure of P2P objects so they can be modified within a collaborative community.

We obtain this goal by associating multiple identifiers with a learning object. The first identifier is called `LOID` (Learning Object Identifier) and multiple versions are identified by a version specific `VSLOID`. Both identifiers follow the same scheme as identifiers in BitTorrent—they are unique 20 byte values generated by computing SHA1 function on the object descriptor. Finally, each version is associated with a *torrent* that allows to download a given learning object.

We need to maintain the associations between the identifiers and an object by storing them in a persistent database. In the spirit of P2P networks, we wanted to use a DHT to store all needed associations as well as the indexing information described below. One choice of a DHT would be to use the Azureus DHT for this purpose, however running an operational service would require upgrading many nodes with our modified version of Azureus, which was difficult to achieve. Instead, we have used an open distributed storage service called OpenDHT, a similar system that presents the same basic DHT interface of the operations $Store(key, value)$ and $Get(key)$. It provides a continuous DHT service over a large number of Planet Lab nodes distributed all over the world.

Our learning objects are thus represented as the following associations of identifiers and stored in OpenDHT as $(key, value)$ pairs (the left part of the association serves as the key and the right part as the value):

```
LOID -> VSLOID
VSLOID -> LOID
```

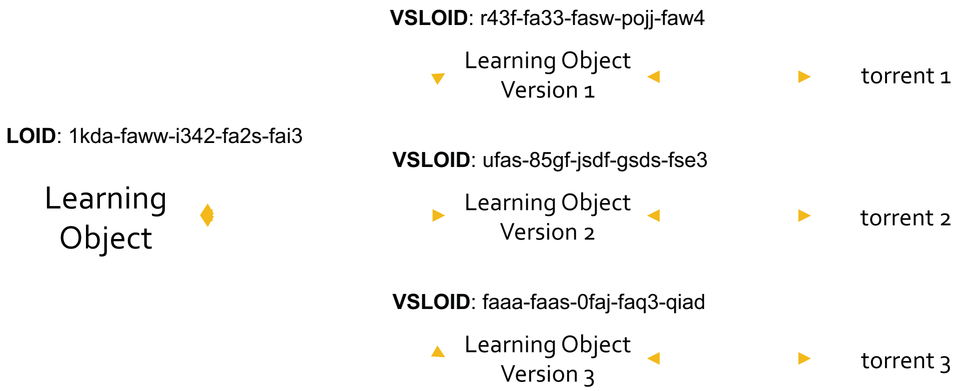

Figure 1. Learning object identifiers.

```
VSLOID -> torrent
```

When we know an identifier of a given learning object, we can retrieve its version identifiers and the torrent information required for downloading. Figure 1 illustrates the notions of `LOID`, `VSLOID`, and their relationships.

IV. Metadata and Domain Ontology

We propose to enable precise searching through the use of *metadata* extracted from a learning object such as traditional attributes Author, Title, Description, and others defined for instance in the Dublin Core [9]. Metadata also includes *concepts* from a domain ontology defined for a given class of learning objects. A domain ontology is a network of domain model concepts (topics, knowledge elements) that defines the elements and the semantic relationships between them [10].

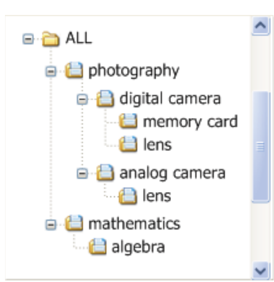

Figure 2. Example of a domain ontology.

Figure 2 presents an example of a predefined ontology with simple inheritance relationships created in the RDF format [11] and built-in in our modified Azureus client. The ontology forms a tree of concepts and terms from the most general one to more specific concepts and terms. For instance, we have the concept of `digital camera` that belongs to the concept of `photography` or `algebra` belonging to `mathematics`. The advantage of using such an ontology is that we can add more general concepts to indexing terms and use them as querying criteria to find related objects. We can obtain an opposite effect for terms that have several meanings—we can distinguish between them by specifying a more general parent concept (such as `lens` for `digital camera`) to restrict a query to more specific and precise results.

Indexing consists of creating an inverted index that associates metadata information with a given `VSLOID` representing a learning object. We use attributes from the SCORM description (Dublin Core) or the LOM part of the object, for instance attributes like `Title: Digital Photography Tips`, `Author: John Smith`. The example attributes are stored in the inverted index as the following relationships:

```
Title_Digital -> VSLOID
Title_Photography -> VSLOID
Title_Tips -> VSLOID
Author_John -> VSLOID
Author_Smith -> VSLOID
```

Similarly to maintaining the structure of a learning object, we store the inverted index in OpenDHT as $(key, value)$ pairs. In the example above, the first association is for instance stored as $key =$ `Title_Digital` and $value =$ `VSLOID`.

When indexing an object, the user can also add indexing terms from the domain ontology. We encode ontology terms by concatenating `ONT` prefix to a term or a concept. Thus, the association has the following form in the DHT:

```
ONT_<TERM> -> VSLOID
```

For instance, when indexing a course on digital photography, the author chooses the concept of `lens` to describe the learning object, we also add more general concepts from the domain ontology—the parent relation between `digital camera` and `photography`. Thus, the following indexes are

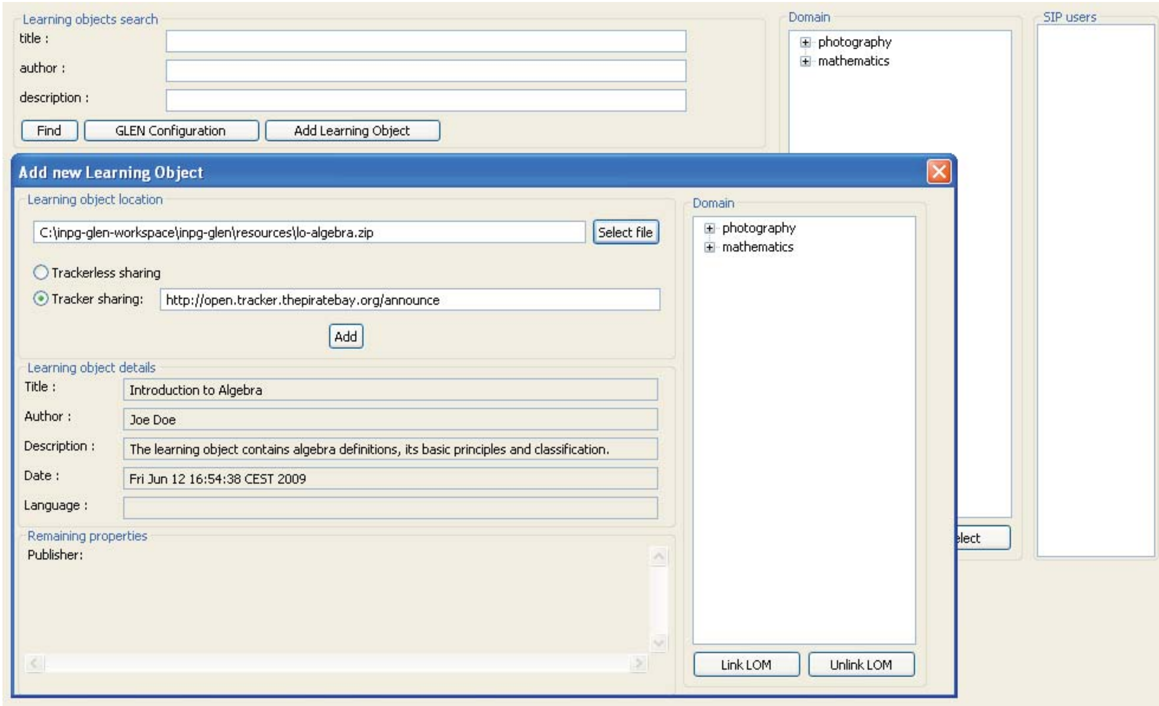

Figure 3. Indexing interface of GLEN.

stored in the DHT:

```
ONT_lens -> VSLOID
ONT_digital-camera -> VSLOID
ONT_photography -> VSLOID
```

Using the ontology for indexing enables for instance finding the course relevant to digital photography even if the user specifies `lens` as the searching term.

Finally, we add support for creating communities by associating the information of VoIP addresses with a given learning object. In this way, those who download a given object can contact other learners in an easy way via VoIP communication. We store the object identifier with the `COM` prefix and the SIP address of the user as the following association in the DHT:

```
COM_'VSLOID' -> SIP-ID
```

When the user finds and downloads an object, we need to present its metadata information to the user. For this goal, we store direct indexes in the DHT—they have the following form in our example:

```
VSLOID -> Title_Digital
VSLOID -> Title_Photography
VSLOID -> Title_Tips
VSLOID -> Author_John
VSLOID -> Author_Smith
VSLOID -> ONT_lens
VSLOID -> ONT_digital-camera
VSLOID -> ONT_photography
```

V. Implementation

We have developed GLEN (Global Lecture Exchange Network), a prototype of a P2P client based on Azureus (Vuze) [5]. We have extended the Azureus interface to offer the function of adding a learning object and searching the network. The indexing and searching schemes presented above use the DHT functionality of OpenDHT. In the current version, we use a tracker for downloading and we work on the development of the trackless version.

To present the possibilities of the prototype, we illustrate its main features. Figure 3 shows the window for adding a new learning object. The user publishes the object in the SCORM format and the most important semantic attributes are extracted from the object. Then, the user can add terms and concepts from the domain ontology (on the right of the figure) with the two main built-in concepts for testing purposes: `photography` and `mathematics`. GLEN stores the indexing information in OpenDHT as described previously and offers a searching interface to the user.

The user can specify search attributes such as title, author, or description keywords, and choose a concept from the domain ontology. The parent terms of the concept are automatically added and the system queries OpenDHT to find relevant `VSLOID`s.

Figure 4 presents the searching interface in which the user specifies `Author: joe`. GLEN retrieves `VSLOID`s linked to the attribute and lists the learning objects relevant to the query (in our example there is only one relevant object—`Introduction to Algebra`). When the user clicks on the title, more details are shown and user can decide to

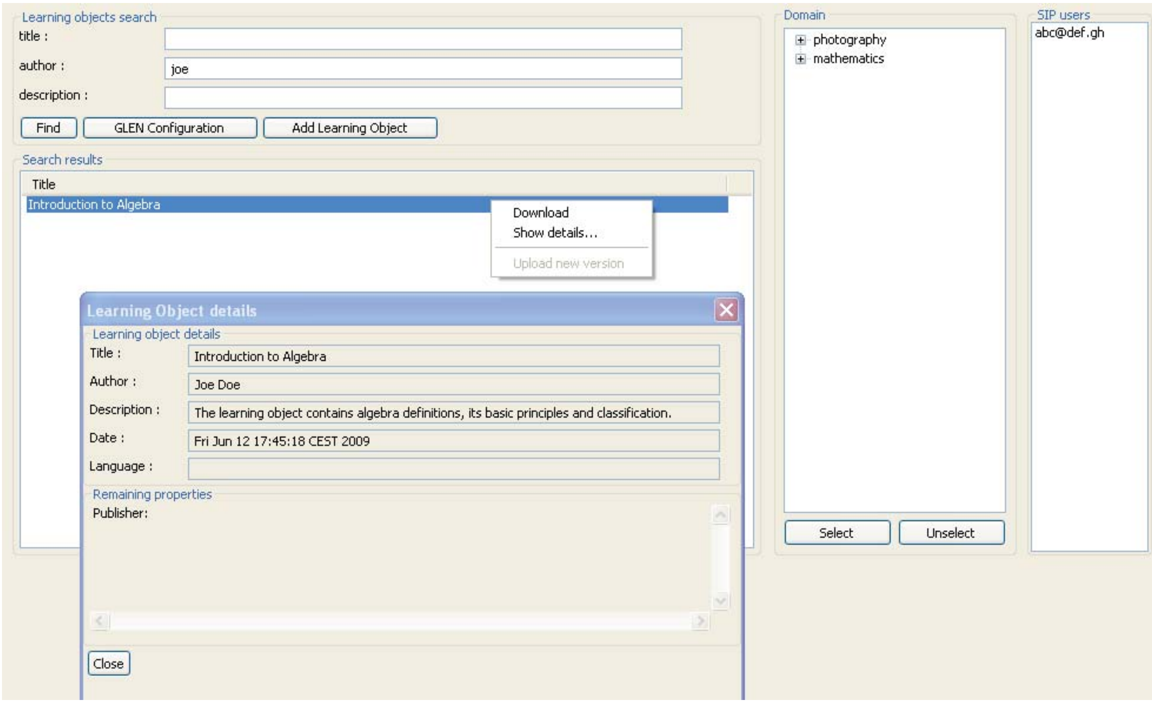

Figure 4. Searching interface of GLEN.

download the object. Its SIP address is stored in OpenDHT and she becomes the member of the community related to the object.

VI. Related work

Some work has already pointed out the importance of applying P2P technologies to education. Edutella has proposed a peer-to-peer architecture for exchanging RDF-based metadata [12]. It builds upon Semantic Web techniques and the JXTA middleware. Its purpose is to make the reuse of globally distributed learning resources easier. Berman and Annexstein has considered P2P technologies as crucial in future educational systems [13]. In particular, they propose to integrate them in a new *personal knowledge management* paradigm, which is useful for students and educators in many activities encountered in everyday teaching, researching, and learning.

Much work considered indexing schemes for P2P networks and we mention here only a few proposals. Felber et al. describe techniques for indexing data in P2P networks based on hierarchically organized multiple indexes and distributed across the nodes of the network [14]. They present several interesting properties, but require a profound modification in the DHT operation of existing systems. Our design attempted to reuse the existing DHT structure for indexing and searching learning objects. Semantic Overlay Networks (SON) represent another approach to searching in P2P networks: nodes connect to other nodes with similar content so that queries can be propagated to appropriate semantically related nodes [15].

Although DHT networks that we used in our indexing scheme offer efficient access to searched items, they can not effectively support partial-match or approximate (proximity) queries. Cohen et al. proposed a design based on unstructured architectures such as Gnutella and FastTrack with the support for partial match queries and relative resilience to peer failures while obtaining orders of magnitude improvement in the efficiency of locating rare items [16].

VII. Conclusion

In this paper, we have presented an approach to enhance current advanced educational tools. Our idea is to take advantage of widely-spread and adopted P2P networks for disseminating learning objects. We consider them as an ideal means for creating collaborative communities of learners with similar interests.

We have described a scheme for indexing and searching complex mutable SCORM learning objects over the P2P network of BitTorrent. We use OpenDHT, an open distributed storage service implemented over Planet Lab to store all needed associations: links between a learning object, its versions, and a torrent, as well as inverted indexes and the information on SIP addresses of community members. Our indexing scheme extends traditional attribute-based approaches with precise indexing terms from a domain ontology. We have enhanced Azureus, an open source BitTorrent client with our indexing support and added a searching interface. Our first experiences with the prototype show that the indexing functionalities contribute to improved searching. We continue to test the support for creating collaborative communities and providing easy VoIP communication between its members.

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Public Displays and Mobile Devices in an Augmented Objects Framework for Ubiquitous Learning

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Abstract— **We are facing promising developments in the area of mobile services where context-aware systems can take the location and position of a user, her preferences and 'smart' objects into account, adding (implicit) interaction between a mobile device (of the user) and the real world. The assimilation of ubiquitous computing by education marks an important step forward, as being pervasive and persistent it allows students to access education calmly, flexibly, and seamlessly. This paper focus on a framework proposal with a well contained and defined application goal in Ubiquitous Computing and a prototype directed for Ubiquitous Learning environments. This system can augment physical objects in an educational environment with additional multimedia information, which is displayed in public shared displays according to the user (student or teacher) that faces the system. The information is contextual, based not only in the object, but also in its specific location, in the environment and in the detected user profile. A generic architecture was designed to help on the implementation of this augmented objects framework in any physical space.**

Keywords- Ubiquitous framework, Mobile devices, Public displays, Augmented objects, Bluetooth, Ubiquitous learning context

I. INTRODUCTION

Ubiquitous Computing (UbiComp) has the main goal of building computing systems that support and facilitate the daily lives of users, but being the least intrusive possible.In 1991, Mark Weiser wrote the article "The Computer for the 21st Century" [1], which outlined his vision for UbiComp, based on the creation of environments saturated with computing and communication facilities, with a smooth and unobtrusive integration. Nowadays, mobile devices, particularly the handheld ones like mobile phones, PDA's and smart phones, are essential tools for our daily living. We are facing promising developments in the area of mobile services where context-aware systems can take the location of a user, her preferences and real objects into account, and add interaction between the user, with a mobile device, and the 'real world'.

The assimilation of UbiComp by education marks an important step forward, as being pervasive and persistent it allows students to access education calmly, flexibly, and seamlessly. The integration of adaptive learning with UbiComp and Ubiquitous Learning (u-learning) offers great innovation in the learning process, allowing its personalisation and customisation to student needs. The term mobile learning is frequently used to refer to the use of handheld mobile devices that enable the learner to be 'on the move', providing anytime anywhere access for learning [2]. With the move of computation into the physical environments in which we live and interact, mobile and ubiquitous computing also provide the opportunity to enhance and support learning in more ways than the 'anywhere, anytime' conception, moving into the u-learning concept. One major opportunity is the facility to digitally augment the 'real world' by linking digital information with physical objects or the environment. Information can be displayed in different ways, e.g., it can be serendipitously 'pinged' through a user passive interaction by using embedded sensor technology and according to various conditions in the learning environment, or it can even be requested with an active interaction by a learner [3].

Following these concepts, this paper introduces a framework proposal and a system based on recognized technologies and directed for u-learning environments. The developed prototype, u-learnEST, is designed for user interaction with situated public displays using mobile devices. This system augments the physical objects, in a learning environment, with additional digital information. It displays information according to the user (student or teacher) that interacts with the system. The information that augments an object is contextual, based not only in the object, but also in its specific location, in the physical space and in the profile of the detected user. A generic supporting architecture is also presented as it was designed to make possible the implementation of this computing framework in any physical space. The implementation of the system u-learnEST was made at the installations of ESTSetúbal (Polytechnic Institute of Setúbal), for an engineering course, although the same concepts could be applied to other places. The main idea was to convert the laboratories of a specific course into big objects 'visited' by multiple users, automatically augmenting them with additional information every time a user is detected in its area. An instance of the system is composed by a situated public display, by a sensor server to manage detections, presentations and communications, and by the mobile devices of the users.

This paper is organized as follows. Section II presents a set of systems with points in common with our project. The requirements and guiding principles for the supporting framework are described in Section III. Section IV is dedicated to the presentation of the supporting framework, highlighting the generic architecture. Section V is dedicated to the implementation of the prototype u-learnEST, with relevance to the architecture instantiation issues and used technologies. Finally, in Section VI, conclusions are made and future work is presented.

II. RELATED WORK

This section presents projects that have application issues, principles and/or applied technologies in common with the present work.

In [4], we presented for the first time a computational framework that would integrate interactions between mobile devices and large displays. The framework was in an initial phase, but led to the present work. Moreover, the divingForPearls prototype [5] is centered on activities distributed by objects/public displays in a museum kind of scenario. Based on ambient information systems [18], the museum's system should be the least intrusive as possible, not distracting the user from the activity considered normal.

We are working on another project, UbiSmartWheel [6], that is also based on the same supporting framework. It is a pervasive biomedical assistive environment for the elderly, with a wheelchair as the smart augmented object, having embedded sensors, an RFID reader and a touch-panel interface. Additionally, interactions with large displays are being integrated in the environment of the application.

ActivitySpot [7] is an interesting framework with relevant points to the present work. It is used to support located activities by occasional visitors of the application spaces. Users are directed to actively interact with the implemented system by personal handheld mobile devices, public displays, and other additional technologies, such as, RFID, Bluetooth or cameras. Therefore, each visitor must be registered as a user with a personal profile. Depending on the action, the system response can be personalized as, for example, presenting information in a display targeted to the user profile.

Rememberer [8], which is based on the Cooltown project [9], works as a tool to capture personal experiences while visiting a museum. The system allows the construction of a record of the visit and may be accessed during or after it. The record is composed by web pages about the visited exhibitions, including annotations and photographs taken during the visit. In the exhibitions, cameras have been installed to take sequences of photographs every time a user requests it making gestures. Initial tests were carried out with RFID technology, with passive tags, as cards or embedded in watches, to indicate that a visit would be to register. Alternatively, PDAs with Wi-Fi communication were also used.

A different project to consider is GroupCast [10] that uses infrared badges to detect audience and present content in a public display to start or enhance conversations between individuals or groups. The correct content is automatically selected according to previous profiles and preferences, defined for each user in the area where the system is implemented. On the other hand, BluScreen [11] uses Bluetooth-enabled mobile devices to influence a public display by detecting the audience around it. Users influence the content of a public display only by their detection, thus having a passive interaction with the system. BluScreen seeks to maximize exposure to the current audience as opposed to matching content to known interests, like GroupCast. The user's passive interaction with the screen (such as stopping in the zone to view the contents) is co-opted to incidentally provide feedback and thereby change the content a user receives in the future.

The DiABlu project is also based on Bluetooth technology and Bluetooth-enabled personal mobile devices [12]. It has the goal of developing a computational framework for the detection of people in an environment. In function of the detection type, there can be created several answers in the form of arts applications. The framework is divided in 3 modules: the server that manages the detections, the Bluetooth-enabled mobile device client, and the final application that receives messages from the server. There is an alternative scenario that allows active interactions between the server and Java-enabled mobile devices.

It is also interesting to focus on projects supporting learning application goals. One of them is the SHAPE project that has the aims: to enhance the conceptual understanding of how to undertake design of computing in public spaces; and to create exemplars for how new computing can be used to augment educational and social interaction in public environments, specifically galleries and museums [13]. A part of the project is used to simulate an archaeology dig, where the aim is to enhance children's collaborative learning in museums, through supporting sensorial experience and capturing embodied knowledge, and using a combination of WebCam shape detection and RFID sensing technology.

One emerging concept of digitally augmented classroom environments is that of 'embedded phenomena', where the augmentation is designed to enable learners to experience various scientific phenomena in the classroom, like in RoomQuake [14]. It implements a classroom embedded with a combination of sensor technologies and physical artifacts used to simulate scientific earthquakes. Pocket PCs served to provide dynamic readings of the simulated earthquakes, which students had to then re-represent as physical models using the physical artifacts.

In the Ambient Wood project [3], a playful learning experience was developed where children could explore and reflect upon a physical environment that had been augmented with a medley of digital abstractions. These were represented in a number of ambient ways, designed to provoke children to stop, wonder and learn when moving through and interacting with aspects of the physical environment. A variety of devices and multimodal displays were used to trigger and present the added digital information, sometimes caused by the children's automatic exploratory movements, and at other times determined by their intentional actions.

UNIWAP [15] is a mobile learning project designed to assist in teacher training. The project used relatively simple technologies, short message service (SMS) and digital pictures, to enable students to create digital portfolios in a central database built from materials created in the field. Messaging was used to enable the trainees, who were widely distributed when training in different schools, to collaborate with each other and share their experiences. Feedback from the participants showed that the immediacy provided by the mobile devices was an important factor. Messages and pictures could be shared immediately with other students. The supervisors benefited from being able to access the material generated by the students in the shared database while travelling between work placements.

Finally, The Augmented Knight's Castle project bases its infrastructure in RFID technology, pointing the pervasive augmentation to a Playmobil playset named "Knight's Empire Castle" [16]. The scenario of the game is educationally enriched and augmented by music, sound effects and verbal comments made by pieces that react to the moves executed by the players. Therefore, they don't use displays with additional information. Some pieces of the set were chosen as the actors of the augmented scenario and were marked with RFID tags. Additionally, it integrates mobile devices equipped with RFID readers for the users' active interaction with the game.

III. REQUIREMENTS AND GUIDING PRINCIPLES

In this section, we identify and describe main requirements and guiding principles for a proper specification of the desired supporting framework for systems like the proposed.

Although, initially, we didn't have the concern to implement ambient information systems, we think that the framework should be directed to follow, as much as possible, the requirements and features of these systems. The other principles are natural options to what was pretended, being adopted as core guidelines in the orientation process of defining the pretended systems.

The framework definition is based on the detection of persons involved in their everyday life activities, which have passive interactions that might be considered incidental with the augmented objects. In a first scenario of application, the basic aim is to ensure that only the detection of the user's co-presence near the object will activate the presentation of additional contextual information in a public display. There is a one to one relationship between an object, or part of it, and a public display. An object can be considered a physical, inanimate and easily viewed entity, or can even be considered as an institution or another user with activity in the environment of the application. In any of these cases, we are augmenting objects by providing embedded contextual information, not available by just looking at them.

The framework should take into account a second level of interaction. Though triggered by a passive interaction, even "incidental", coming from the co-presence of the user in the environment, there can be an active interaction with the object/display pair, using for this purpose ordinary personal handheld mobile devices. These devices also allow the provision of additional information in a private mode.

Fig. 1 shows a generic scenario of application where a user interacts with smart objects that are augmented, mainly, through a public situated display. The guiding principles are followed in a kind of scenario where the present work application is inserted.

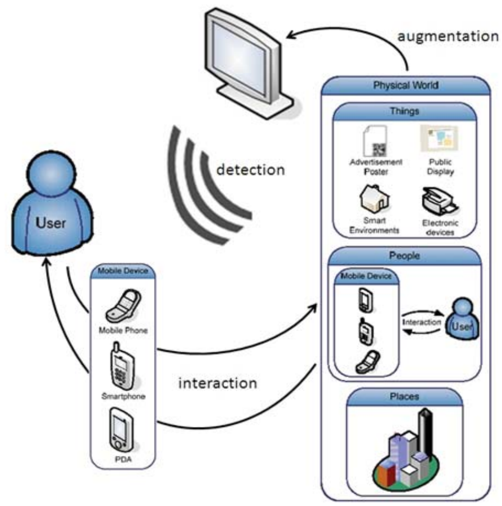

Figure 1. Generic scenario: user detection, object visual augmentation and active interaction between user and object (adapted from [17]).

A. *Principles*

After the definition of the main requirements, the guiding principles are clearly described as follows:

- Ambient Information System Concept

Considered a sub-domain of Ubicomp, the concept of Ambient Information System (AIS) has the main goal of presenting information through smooth and integrated changes in the environment, allowing that users are not distracted from their regular tasks, but being able to receive and be aware of not critical additional information. Being this a recent research area, there is still no commonly accepted definition for these systems, but Pousman et al. [18] attempted to unify the various existing terms, proposing the name used here and setting the following main features: 1) Show important, but not critical, information; 2) Getting attention from the periphery to the centre, and vice versa; 3) Aesthetically pleasing and environmentally appropriate integration; 4) Presentation of subtle changes to reflect updates in information (not to be focus of distraction); and 5) Preference for the use of existing resources in the environment for information presentation.

- Incidental Interactions with Co-Presence Notion

The notion of "incidental interactions" was proposed by Alan Dix to describe actions that are co-opted by a system to serve a purpose other than the one initially thought [19]. An incidental interaction can be seen as a situation where actions executed for another purpose (or unconscious signals) are interpreted in order to improve future interactions in everyday life. This notion is important for the present work, since the framework should start with the user interaction with an object to automatically augment it, without an obvious additional effort by the user.

It should be noted that incidentally does not imply that an action, or the subsequent goal, is not intentional. The user may have previously specified to the system its intention not needing to think consciously while performing the corresponding actions. Incidental interactions also differ in terms of feedback received by users. In a traditional application, the feedback received by the user about its actions will be direct, explicit. However, in an interaction called incidental, this feedback may be, in many cases, minimal, discrete and even delayed. Related with these interactions is the detection of persons that allow the computation of co-presence to be embodied within the real–world. The embodiment means that through normal real-world interactions, a user automatically participates in co-presence systems, without the need of participating in activities outside of his normal daily routine [20]. In a computational system, a technological solution, like RFID or mobile devices, should exist to detect the user co-presence.

- Use of Public Situated Displays

There are two trends, somewhat conflicting, with regard to providing information and services in collaborative environments [21]. The first directs itself to the use of public situated shared displays that can cover a wide audience while the second explores the mobility of small displays on mobile devices to offer more personalized content. Public displays, categorized as "boards" and preferably large, exist in various forms and scales, including, for example, street displays (used mainly for advertisement), projection displays used at conferences and in schools, kiosks, and even small screens next to objects. On the other hand, the second trend is related to mobile devices such as mobile phones, laptops and PDAs, which function not only as input for interactions with systems, but also as displays. These devices offer more personalization options, but the limited computational power and small displays, limit a more dynamic presentation.

Beyond other referred points, since public situated displays offer greater power and a better resolution for the presentation and combination of information, the framework's architecture presents a component that takes into account their integration in a system. In a first approach, the goal is to have the information that augments an object displayed next to it, with the display being a direct extension of the object. Thus, the action to augment the object becomes, initially, contained and dependent on the user approximation, being less intrusive and not forcing the user to take an active interaction. According to their availability and access modality, the framework's displays are categorized as: public, shared, proactive and even interactive [22].

- Ubiquity of Mobile Devices

Nowadays, handheld mobile devices are essential tools for our daily living, being present when interactions between users and objects occur in computational environments. So, they are becoming ubiquitous computational devices, since they find themselves in almost all locations, and are almost universally connectable. In parallel with the evolution of the available functionalities it also increased the diversity and capacity of wireless communication technologies of the devices.

Therefore, the proposed framework should take into account the ubiquity of the mobile devices. Depending on the context and type of physical space for application, the devices may be valuable tools when used for the detection of users. Thus, the space or the objects can feel the co-presence of a user in a natural and non-intrusive way. The user does not need to carry an extra identifier to be recognized in an application scenario. To accomplish this, using personal devices, it is assumed that there is a one to one relation between a user and her personal mobile device. An object/display pair can detect the co-presence of a device with the use of, preferably, one short-range wireless communication technology. Moreover, in a complementary option, the devices are used as tools to add to the framework active interactions and more personalized information. Knowing that situated displays are the choice in many Ubicomp systems, others prefer to use the small screens of mobile devices for mobility and personalization flexibility purposes [23].

The framework should enable the object augmentation through the combination of large public situated displays with small private mobile displays.

- Embedded Contextual Information

An environment may contain only one display or even a large number of display devices distributed in the environment and close to respective objects, casually available to environment users. The aim is to provide contextual information at decision points, which are where the objects are placed or exist. This process can be seen, merely, as a simple action of getting more and better information about an object, but also as an aid to make better decisions regarding the activities to be performed in an augmented space.

Therefore, it is considered that augmenting objects through situated displays is to provide additional information integrated, embedded, in the corresponding context. This option does not prevent the mobile devices displays to be used, as they can also be embedded in the context. Following this principle, it is essential to point that the information presentation is made where and when is needed, being as unobtrusive as possible, and with passive interaction [24]. Finally, the information that augments an object is contextual, based on not only in the object, but also in its specific location, in the physical space, or application scenario, and in the profile of the detected user.

IV. THE SUPPORTING FRAMEWORK'S ARCHITECTURE

This section is dedicated to the presentation of a generic and modular supporting architecture [25]. The architecture must be comprehensive, covering various types of scenarios. A generic modular architecture permits to maximize its application in different scenarios, decreasing the duration time of the systems' implementation phase. This approach allows us to understand how the various components can and should connect, adapting the architecture to the needs of each application project.

A. General Architecture

The implementation of a pervasive system to augment physical objects with additional contextual digital information involves multiple components and presents some particular issues. The proposed architecture for the system is based on three main basic components, which can be viewed as generic and independent modules, corresponding to three layers of implementation (Fig. 2). The components are the following:

- Tracking - Any application of this type must have a mechanism for identification and location of the user/device (tag). Additionally, this component can be extended to include an interface for short-range communication with the user.
- Application Core - This is the component responsible for implementing the application logic of the scenario. It must be able to analyze and process the information given by the module described above, crossing it with the contextual information related to the object. This component represents the independence of the application, which depends on the scenario and relative goals.
- Display Interface - In this work, displays were considered (the used technology varies with the application) as being versatile enough to achieve a reliable, rich and less intrusive representation of the extra information.

The three listed components are in the augmented object layer, considering the fundamental principle of pro-activity of the object/display pair in relation to the user. The latter can be seen as a simple tag (e.g., RFID or Bluetooth-enabled mobile phone) which has a passive interaction, resulting from her natural presence in the scenario of application. Additionally, for active interactions scenarios, the architecture provides a component for the mobile augmentation of the object. In this case, besides the public situated visual augmentation, the tracking component provides an extended augmentation communication module and the user is more than just a tag. Using a mobile device, which can be personal, enables communication with the object through short-range technologies or via GPRS/UMTS. It also allows viewing private information on the screen of the device, working as a supplement to the public display.

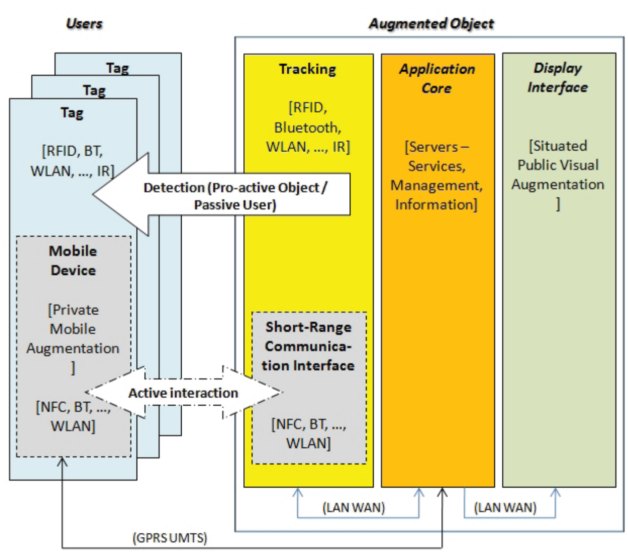

Figure 2. Main components of the general architecture.

The proposal can be seen as typical client/server architecture, given a set of servers dedicated to providing information to various clients. Therefore, the set formed by the user and the object can be seen as a client. Both the Tracking and the Interface components are considered close to the object, thus, being on the client side. The presence of the user in the area of the object is detected by the Tracking component that requests a service to the Application Core, the server. This one sends the results to the Display Interface. It can also communicate directly with the Tracking component, and even with the user's mobile device. Depending on the application scenario, the Application Core can be shared by several clients (objects) or be dedicated to only one object, with the latter having an extension by several users with mobile devices.

Since there are several modules/components communicating with each other, which may be remotes, it is necessary to have an interface for communications (which includes, e.g., NFC, Bluetooth, GPRS and/or WAN/LAN) capable of supporting, in a transparent and efficient way, the data communication between those modules.

B. *Architecture's Main Modules*

Fig. 3 presents a detailed architecture of the components corresponding to the augmented object layer, thus, only showing how the infrastructure faces the primary principle of user's passive interaction (or object's pro-activity). It follows a detailed description of all the architecture's main modules.

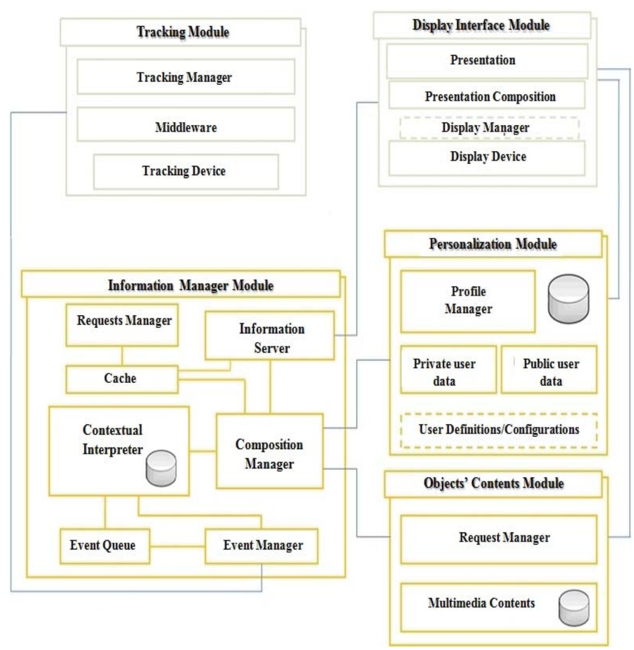

Figure 3. Architecture´s modules (augmented object components).

- **Tracking**:

This module is the basic complement to the object visual augmentation, and it is essential for any system implementation. It is responsible for the detection and identification of users, adding to the object the ability to perceive human co-presence (through technological means). Through this module, it is possible to know how much time a user spent in the pre-defined object area. There are several technologies that can be used with this module (e.g., RFID and Bluetooth). So, it is advisable to create an abstraction layer – Tracking Manager – to work as output interface, providing, transparently and uniformly, all data to the application core. Also noteworthy is the Middleware layer, which is dependent on chosen technology for a specific project development. This layer makes the abstraction of the Tracking Devices (hardware) used in the implementation, being essential for the top layer, which thus only has to integrate the interface(s) provided by the Middleware.

- **Display Interface**:

It is the real output module of an implemented system, being responsible for the final Presentation of the contextual information about an object. It can be programmed to integrate and provide other services, in case it is pretended to complement the main service of information presentation. The information should be presented to the user as soon as possible, verifying the lowest latency time between the user detection moment and information visualization. The application scenario, and in particular the users rate in the space, is crucial to the display technology choice. Since there is a great diversity for this choice, there may be a need to create an abstraction/management layer - Device Manager - for certain use cases, i.e., o create uniform protocols for the management of the Display Device(s), facilitating the programming of the Presentation Compositor sub-module. This module requests and receives messages from the server of the application module. These messages provide information about those involved in the interaction, i.e., object, user and her profile, and also the information type, which is the element that indicates what type of graphical user interface must be built/used. It also makes requests to the Personalization and Object's Contents modules to obtain the final content for presentation.

- **Personalization and Object's Contents (in Application Core component)**:

The first module acts as a data service that manages the application profiles and user data, and may include an optional sub-module for individual settings. The Object's Contents is another data service that is 'responsible' for the data repository about the scenario's objects. The repository is typically large and bulky, including a wide variety of multimedia content, such as text, sound, image and video.

- **Information Manager (in Application Core component)**:

The system architecture is event oriented because each time the user changes her status, i.e., being, or ceasing to be, detected next to an object/display pair, this is an event for which there is a handler, ensuring the application status update. The main entry of this module is the Event Manager, which controls the inputs generated by the Tracking module.

The module core is composed of a Contextual Interpreter (CI) and a Composition Manager (CM). After getting information from the Tracking module, the CI is responsible for correlating the detected user, which has a specific profile, with the detected object to obtain the corresponding additional information. As a next step, it sends a message (document) to the CM, giving knowledge about the executed interpretation. The CM sub-module combines this information with data gathered from data servers, producing another document to send to the Information Server. The document must also be produced according to the detection or request origin. If the CM has received a message from the CI, then the produced document must contain a minimum of information, because it is directed to the Display Interface module. In case the received request is from a mobile device (in an active interaction context), then the produced document must be the final, containing all the information asked or expected. Depending on the scenario of application, the CM can also take into account, for example, the local settings, user preferences, and object location. This composition module is the responsible for composing, structuring and selecting the information to be displayed.

The CM sub-module is dependent on the application, but the CI sub-module is completely independent, having a supporting model (architecture) prepared to suit any scenario. The model works for a scenario composed of multiple objects, such as a museum room, but also in cases where a conceptual large object is considered, such as an institution. It allows the association of multiple displays to one object, being useful in institutions scenarios.

The Information Server provides the final documents, created by CM, for both the Display Interface and the requests made by mobile devices, which are integrated in the infrastructure for active interactions. As for the Requests Manager, this is responsible for the information transmitted to the Tracking module, which can also perform a short-range communication with mobile devices.

C. Mobile Augmentation Modules

The generic architecture also presents an additional blue layer on the user side (Fig. 2). It will be implemented every time mobile devices are used in applications. Fig. 4 (left image) presents the Mobile Augmentation module that provides to the user an object additional augmentation, which can go outside the environment of application.

It allows the direct communication with the Tracking module, via short-range technology, and long distance communication with the Information Manager system. It has a Communication Manager that provides an abstraction in relation to the technology used for connectivity. This will make the programming of the Mobile Manager/Presentation (application) pair less complex and independent of used technology. The Mobile Manager includes an optional sub-module for management services, providing the facilities made available to the user in the process of enhancing the object, being strongly dependent on technology.

To accomplish the mobile augmentation purpose, on the Tracking module of the object layer, a new sub-module was integrated in Tracking Manager. Called SRCI (Short-Range Communication Interface), it permits the manager to be aware of devices that want to communicate with him. As an alternative to the near active interaction there is the possibility of the device to make direct requests to the application core (e.g., via GPRS), which provides augmentation documents in the Information Server. The purpose of this paper is not to present a detailed specification of the manager modules, but there are two important issues that should be described at this point, taking into account their importance to the present work. The first one is related to the possibility of SMS communication between the mobile client and the server and the second one is related to the CL competitive module.

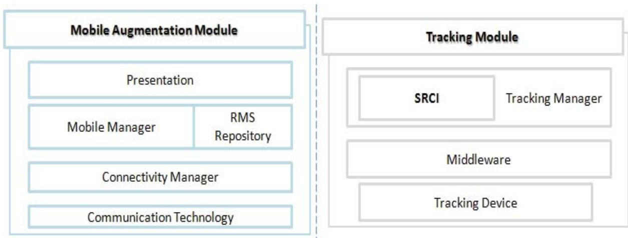

Figure 4. (left) Module of the mobile device and (right) SRCI addition to the Tracking module.

V. THE U-LEARNEST PROJECT IMPLEMENTATION

The implementation of the system u-learnEST was made at the installations of ESTSetúbal, for an engineering course, although the same concepts could be applied to other places. The main idea was to convert the laboratories of a specific course into big objects 'visited' by multiple users (students and teachers), automatically augmenting them with additional information every time a user is detected in its area. This information can be generic, for any kind of user, or personalized and directed to users with a know profile. For this system, the goal was to follow all the proposed principles, with particular focus on the ubiquity of mobile devices, thus, to implement an application with human active interactions.

The system is composed by a public shared display, a computer (the server) to manage the detections, and by the mobile devices of the users. The display was placed at the entrance of a main course laboratory, with the server close to it. Bluetooth (BT) was adopted as the communication and detection technology and Java, in the J2SE (Java 2 Standard Edition) and J2ME (Java 2 Micro Edition) platforms, was the basic language for software development. We can find almost a Bluetooth sensor attached to any person, through the mobile devices. This aligns well with the embodiment principle wanted for the system. A student going to a laboratory lesson would have an incidental interaction with the system, having the opportunity to interact actively with the u-learnEST system. For this, a client application was created for the mobile devices registered in the system. When an unregistered device appears, it is asked to register and to install the application to maximize the capabilities of the system. It is not necessary to have the client application installed to be registered.

Fig. 8 illustrates the implemented architecture for the present system. Regarding the instantiation issues, it is important to focus only on those considered determinant. In relation to the Tracking Device, a USB Bluetooth dongle connected to the server transform it in a Bluetooth device, being able to detect and to communicate with Bluetooth-enabled mobile devices. The Middleware module integrates three layers, with focus on the JSR-82 API [26]. The JSR-82 hides the complexity of the BT protocols stack, providing a simple set of API's for Java development. Since initially the JSR-82 API was only implemented for mobile devices, it was needed to use the BlueCove [27] implementation of it for J2SE. The Tracking Manager uses the BlueCove API and was programmed exactly as the correspondent in the other prototype. But, in this case, it interfaces directly with an Event Manager in the Application Core. Due to the fact that detecting "BT tags" does not work exactly as detecting RFID tags, this module has to manage the XML messages received from the previous module, filtering and organizing them for the Contextual Interpreter (CI). Its programming must be set and changed according to the conditions to be established for the system application.

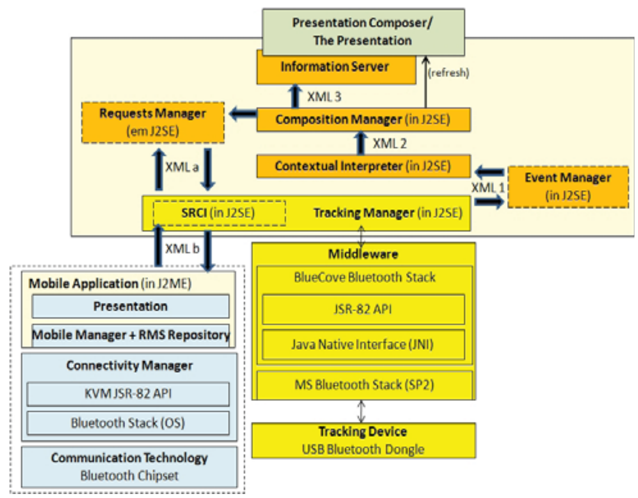

Figure 5. Architecture instantiation for the u-learnEST project.

The Application Core component includes three important implemented sub-modules: Contextual Interpreter, Composition Manager and Information Server. The first two are written in Java and the latter is a web server, which receives HTTP requests, and all the communication messages between them are XML documents (see Fig. 5). The Contextual Interpreter module is the system's "decision maker", processing data received from the Tracking Manager. Upon receiving a XML document with a detection indication, it makes an immediate processing, followed by the update of its contextual information database. Thus, knowing the object, next to which is the user, will determine what additional information to display and where to do it. With the contextual data determined, a second XML document (XML 2) is created and passed to the Composition Manager (CM) module. This one is responsible for placing a third document (XML 3) in the right folder of the Information Server. A folder for each object/display pair was created in the Information Server, with names according to the corresponding displays names. This is how the CM module knows where to place the generated XML

/

document. Before doing so, it processes the XML document passed by the previous module. It questions the Personalization module to retrieve some data about the detected user and the Objects' Content module to retrieve a portion of information that is essentially text. An element in XML 2 indicates if the additional information has text in its composition, beyond the generic summary that is already included. Content such as image or video will be retrieved from the database only by the Presentation Composer sub-module. Finally, the module automatically refreshes an XHTML file that is in the folder where the XML 3 document was previously placed.

The Composition Manager has one more task, the creation of XML documents with information to be accessed by mobile devices. The document is made available to the Requests Manager, thus, being available to be requested by a mobile device. In case a mobile device does not implement the API JSR-82, it may be placed in the Information Server. The server also has a folder for each mobile device, which using GPRS may request the most recent document.

In this prototype, the **SRCI** module was implemented to complement the Tracking Manager. It can start communicating with one of the discovered devices, but for this application it was programmed only to accept RFCOMM communication requests coming from users. When the mobile application requests a communication, the SRCI queries the Requests Manager database to obtain the XML document that refers to the device.

A. Mobile Application Development

The Mobile Application client is developed in Java (J2ME) for devices that support the MID profile [28]. It has two main modules:

- One with services to interact with the server via Bluetooth (Connectivity Manager with two layers);
- Another one to manage the possible information received from the system (Mobile Manager).

Not all the mobile devices can run the first module to interact directly with the system. To accomplish that, the device must be embedded with the JSR-82 API. If a device does not embed the API, the solution is the direct communication with the Information Server, where the object has an URL address to be accessed through WAP. In this way, the user will be able to receive XML documents to consult later and to store them in the client repository, a Record Management System (RMS).

The module to manage the received information uses the kXML library in its implementation to make the parsing of the XML documents [29]. kXML provides an XML pull parser and writer suitable for all Java platforms, including J2ME. Because of its small footprint size, it is especially suited for Java applications running on mobile devices.

Summarizing, the client application allows the user (mainly, students) to:

- Discover nearby servers and connect to one (JSR-82 dependent). This makes it possible for the user to choose to interact with one from a number of nearby installations, although the existence of only one in the system implemented.
- Send a XML message or keystrokes to the u-learnEST server (via Bluetooth or web server).
- Receive information in a XML structure. This makes it possible for the user to receive personal and private information.
- Store received information.
- Visualize information after "disconnecting" from the system (Fig. 6).

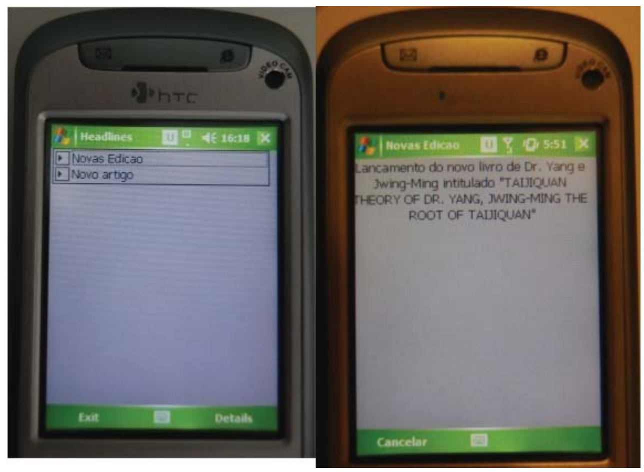

Figure 6. Earlier examples of mobile application screens.

VI. CONCLUSIONS AND FUTURE WORK

The current status of the prototype, using mobile devices and public displays, leads us to think that the system's framework is generic enough to deal with most interactions between the users and the 'laboratory object', even supported by different types of technologies. Although we have not yet carried out thorough usability and functional studies, we believe that the presented framework is also generic enough to accommodate different types of application scenarios, in terms of implementation issues.

The use of m-learning and u-learning tools, if correctly conceptualized and built, constitutes an efficient complementary tool to the traditional teaching methods. Students' information can be dynamically integrated over time and space, broadening and connecting students' understandings, both in the physical world and in classroom settings. Therefore, the u-learnEST project is an important asset to education, because it automatically complements the traditional learning environment without needing special devices from students, the main users of the system.

For future work, we are planning to update the mobile application interfaces with better design and functionality. In relation to interactions with users, we intend to carry out thorough usability, human-computer interfaces and personalization studies. Right now, we are conducting a questionnaire survey among 20 students that tested the system in order to determine their satisfaction and opinions.

Acknowledgment

I would like to thank to Prof. Nuno Correia for the great job coordinating our general work that led to the development of the framework and the system implementation.

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Adaptation in a PoEML-based E-learning Platform

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Abstract—**In EML-based e-learning platforms for engineering education, adaptation can be focused whether in the EML meta-model or in the run-time environment. In the approach centered in the EML meta-model, adaptation is carried out by advanced modeling and late modeling. In the approach based on the run-time system, it is the run-time system the one that supports the change types that are allowed. This paper presents a conceptual framework and software architecture aimed to support late modeling in an e-learning system based on PoEML (Perspective-oriented Educational Modeling Language).**

***Keywords*— CSCL, adaptation, late modeling**

I. Introduction

In the last years, it has been developed a new approach to e-learning systems design, based on Educational Modeling Languages (EMLs). Those languages enable the definition of a Unit of Learning (UoL) independently from the final system used for delivering the UoL, enabling thus a certain degree of reuse in the design of UoLs [1]. This approach supports the definition of UoLs in a pedagogy-independent way.

Unlike both implicit and explicit models that manage contents, an EML not only describes the static content structure of a UoL, but it also accurately describes dynamic issues such as activities to perform, composition of groups of participants, the order between activities, etc. Therefore, the description of a UoL implies the description of a process. The process described by an EML can be of collaborative nature, that is, several participants collaborate in order to achieve a common goal. That is a difference from languages as SCORM (ADL) [2], which only allows for the definition of processes in which only one participant is involved.

The PoEML language [3] is within this conceptual framework. This modeling language has been designed following a separation-of-concerns approach, encapsulating thus quasi-independent parts of a UoL model in separate aspects/perspectives.

The UoLs described by an EML have a life cycle that can be decomposed into the following phases:

- Authoring: in this phase, the UoL is designed by making use of an authoring tool. This phase is also known as design-time.
- Publication: in this phase, the UoL is imported into an execution engine.
- Delivering: in this phase, the participants perform the UoL. This phase is also known as run-time.

In the Figure 1, it is shown how the author of a UoL publishes it into a Learning Management System (LMS) after the authoring phase.

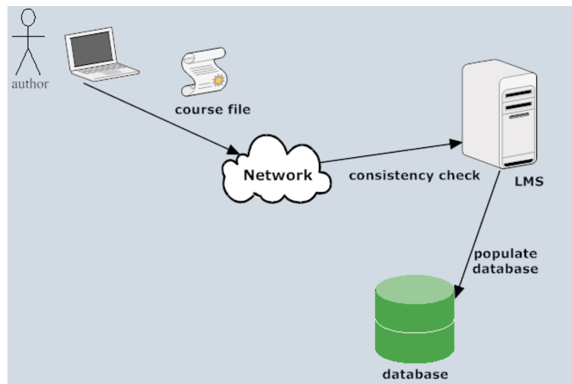

Figure 1. Authoring and publishing of a UoL.

In systems based on EMLs, methods for promoting learning are in the form of structured processes. Collaboration systems based on processes, whose most representative developments are the WfMSs [4], indicate a process specification in which the activities to be performed by the different actors are defined. Due to their characteristics, those systems are very similar to EMLs, and therefore they are relevant for this study.

Some works have proposed to transform processes modeled with an EML to processes modeled with a workflow language [5] [6]. In this work [7], an EML is even used as a true workflow language. Because of the reasons already mentioned, we will refer to EML-based e-learning systems as a type of process-based system.

A main issue in EML-based e-learning systems is that of the adaptation [8]. Late modeling allows designers to leave some parts of the UoL unmodeled until run-time. Often, designers may prefer to model the most relevant parts of the UoL, remaining the rest to be modeled at run-time. Therefore, it is required to support incomplete (or abstract) models, which will be specified during run-time.

This paper introduces both a conceptual framework and software architecture for supporting late modeling of PoEML learnflows.

II. COMMON APPROACHES TO ADAPTATION

From a technical point of view, there are some mechanisms that are used to carry out adaptation. In order to support adaptation in process-based systems, it is necessary to take into account some aspects both from the definition of processes (design-time) as well as from the execution of processes (run-time). Next, we discuss those approaches following the classification in [9]:

- Approach centered in process definition meta-model
  - Advanced modeling
  - Late modeling
- Approach centered in the execution system
  - Type adaptation (evolutionary change)
  - Instance adaptation (ad-hoc change)

A. Approach centered in process definition meta-model

In the approach centered in the process definition meta-model, it is the meta-model the one that determines the structure and the allowed types of changes. The following lines are considered: advanced modeling and late modeling.

Advanced modeling allows authors to consider alternatives during design-time. In this case, the different alternatives (learning paths) that are allowed during execution are modeled in the process definition at design-time. Despite the fact that a UoL has well-defined objectives, those can be achieved by different routes, depending for example on the student's performance. The support of this requisite is more complex if we consider alternatives in every concern that can be modeled (data, participants, time-constraints, etc). Therefore, an EML might allow for the modeling of alternatives in the different concerns involved in a UoL. That modeling of alternatives should be done in a manageable and compact way.

During run-time it should be possible to select one of those alternatives. There are two main ways to do the selection [10]:

- In accordance with the state of execution. Using conditions that are evaluated in specific points (e.g. at the start of an activity) or events that that happen at any time. The state can be related with the characteristics of participants, results obtained in past activities, etc.
- In accordance with the decision of an authorized participant. In traditional education, often teachers make decisions on the best way to achieve learning objectives.

Late modeling allows for leaving some parts of the design without being modeled, in order to be modeled during run-time. Some parts of the process definition are leaved as black-boxes, in order to be modeled during execution. In [10] late modeling is dealt with as a dynamic refining of the models. Often, some parts of a UoL may not have a clear solution and it may be not possible to model them. Designers may prefer to model the most relevant parts and leave without modeling the less relevant ones until run-time. Therefore, it is required to support incomplete (or abstract) models that will be specified during run-time.

B. Approach centered in the execution system

In the approach centered in the execution system, it is the execution system the one that supports the types of change that are allowed. The following lines are considered: instance adaptation and type adaptation.

Instance adaptation is usually named exception management. An exception can be seen as an occasional deviation from the normal behavior of a process. Exception management is needed for dealing with the deviation in run-time from the execution plan foreseen during design-time [11]. In the e-learning field, an exception can be produced when the model is deficient in some realization of the process, as when a certain route (learning path) is over dimensioned respect to other learning paths, causing in this way a competitive disadvantage to the learner that has followed the over dimensioned route. In that case, exception management is in charge of correcting that wrong situation, without need for stopping all process instances, fix the model, and enact all the instances again.

Type adaptation deals with process instance migration during a process execution from an old schema to a new one. One of the main problems in this approach is to make a migration of the process execution state to the new one [12]. Type adaptation can be presented as a dynamic evolution of the model, that is to say, the UoL model described with an EML is able to evolute in time to adapt itself to new situations, for example: the change in a study planning, more learners that expected, a new approach to teach some contents, etc.

III. A LATE MODELING EXAMPLE OF A POEML LEARNFLOW

Educational Modeling Languages such as PoEML have a static view of the world, and they do not support evolutionary and dynamic changes. In the literature, there are many works addressing the lack of flexibility and/or of adaptation in EML-based e-learning systems, such as [13] [14].

Figure 2 shows an example of collaborative practice formalized with PoEML. In this example, it can be seen how the work is divided into three independent activities (corresponding to each one of the Newton's three laws of motion), which are assigned to three different participants. Each activity is reviewed by a different participant. When the reviews of the three participants are positive, the three participants have to edit collaboratively a document that reflects the work performed in the previous three activities. Finally, the teacher makes an evaluation of the last activity, resulting in one of three possible flows (finish, minor revision, major revision). The example learnflow can be carried out just by using a wiki engine for edition and basic HTML forms for assessment by the teacher.

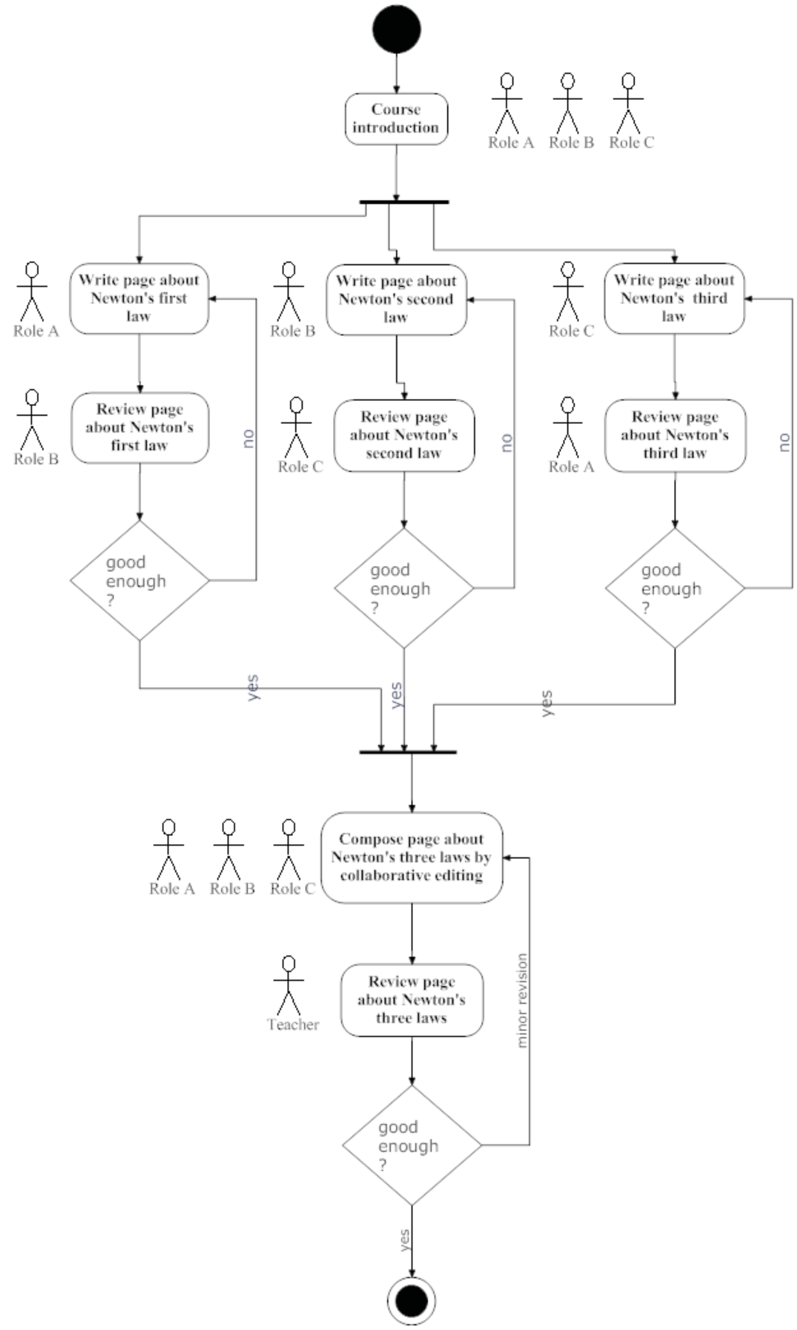

Figure 2 A PoEML learnflow

A collaborative activity is shown in Figure 3. It is worth noting that the edition of a page in a wiki is a kind of activity with no explicit end. In this case the end of the activity will be the temporal deadline. Using PoEML as the modeling language, this collaborative activity is modeled as a `educational scenario` in which there are three roles involved.

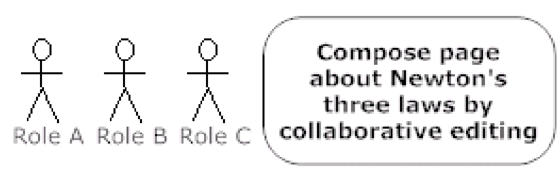

Figure 3. Collaboration at an activity level

The graphical flow-based representation in the Figure 2 is useful to put into manifest the sequencing of operations in a learnflow. Notwithstanding, we will follow an aspect-oriented approach in which the different aspects that compose a learnflow are treated in a quasi-independent way. Thus, in the learnflow of the Figure 2 several aspects can be identified:

The initial `scenario` is shown in Figure 4.

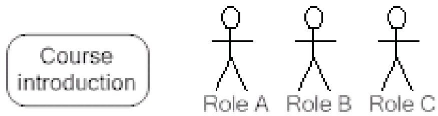

Figure 4. Initial scenario in the learnflow

Once the initial `scenario` is finished, three `scenarios` are launched in parallel. In the Figure 5 it is shown one of those three parallel `scenarios`.

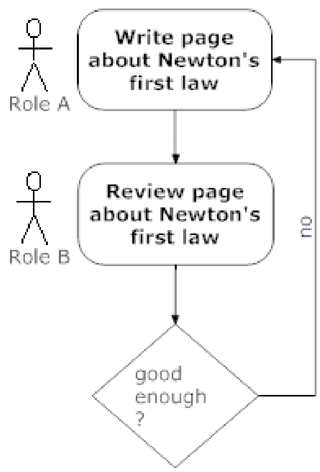

Figure 5. One of the three parallel scenarios in the learnflow

Finally, participants are requested to perform a collaborative activity, which is evaluated by the teacher. Figure 6 shows that final `scenario`.

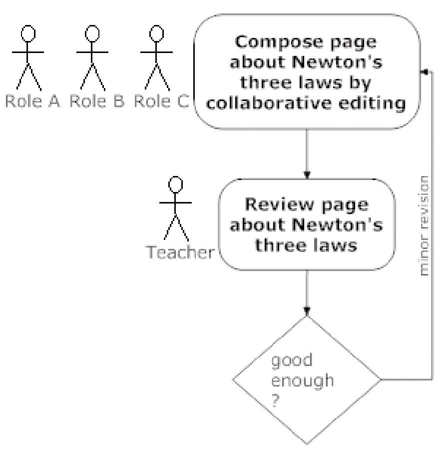

Figure 6. Final scenario in the learnflow

The ordering of `scenarios` is shown in Figure 7.

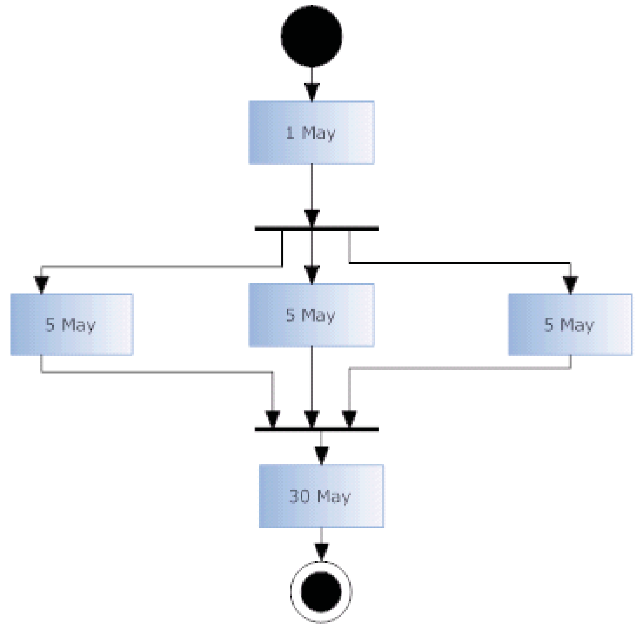

Figure 7. Order and temporal view of scenarios

In the activity *Write page about Newton's first law*, the work for the assigned participant can be specified in more detail. For example, the content of the fist law page might contain: formulation, history, and example of application. In order to leave unspecified the nuts and bolts of the activity *Write page about Newton's first law* in run-time, a *placeholder* activity must be placed during design-time. In this way, the content of the placeholder activity can be specified during run-time, and thus adapted to both teacher's and learners' preferences. With this approach it is obtained a good grade of freedom in design.

In design-time it is just not possible to foresee the behavior of learners. It is necessary to wait until run-time to monitor the learners' reactions and performance. The teacher may want to tune the model in some ways:

- Adding more activities
- Changing the temporal constraints for activity finishing
- Adding/skipping a `goal`, etc.

In the next section we will see the procedure for adding/editing/removing elements of the model.

IV. LATE MODELING OF POEML LEARNFLOWS: AN ASPECT-ORIENTED APPROACH

Following an aspect-oriented approach, the allowed changes in the model can be systematically categorized in *aspects*, each one dealing with a specific concern. In Table 1, it is shown a systematic categorization of run-time changes.

In the literature there are some works such as [13] aimed at providing run-time adaptation in an aspect-oriented way. In the referred works, the underlying model is not aspect-oriented, unlike the PoEML case. So, the PoEML aspect-orientation is a grant for easier aspect-oriented changes during run-time.

A. Situating placeholders in the UoL model

Many times, the complete structure of a UoL cannot be specified during design-time. In that case, it is desirable to count with late modeling support, which provides the needed flexibility to model the remaining parts of a UoL at run-time.

The approach here is to use a special type of construct, named *placeholder*. The placeholder occupies the place of the unmodeled `element` or `specification`. Thus, there will be as many placeholders as types of constructs in the EML at use. In the PoEML case, we identify the following placeholder types (Table 1), in accordance with the `educational scenario` meta-model in Figure 8. This table puts into manifest the aspect composition feature in our approach. The `scenario` placeholder may be composed of placeholders for `goals`, `environments`, `order specification`, and `temporal specification`. In the same way, the `environment` placeholder contains at least a `tool` placeholder.

Placeholder type	Contained placeholders
Scenario placeholder	Goal placeholder, environment placeholder, order placeholder, temporal placeholder
Goal placeholder	
Environment placeholder	Tool placeholder
Tool placeholder	
Order placeholder	
Temporal placeholder	

Table 1. Placeholder classification

The `scenario` placeholder is a black box that reserves space for a `scenario` model. The language constructs will be added at run-time in the space kept by the placeholder.

The `goal` placeholder reserves the space for the definition of a learning objective.

The `data` placeholder is used for reserving the space to add resources and/or activities to a UoL at run-time.

The `order` placeholder keeps the space for adding ordering constraints at run-time.

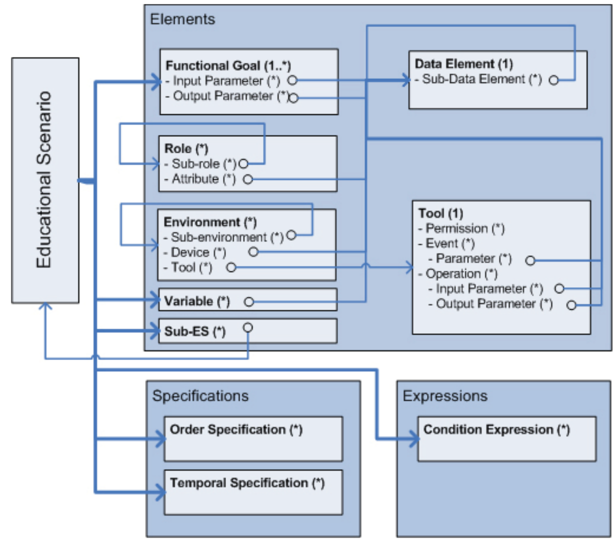

Figure 8. Elements in an Educational Scenario

The `temporal` placeholder enables the deferred definition of temporal constraints in the Unit of Learning.

Finally, the `participants'` placeholder can be situated in the place of the complete specification of `participants'` roles in the UoL.

B. Modeling black-boxes (placeholders) at run-time

When in a learnflow instance the execution flow reaches a black box, the `educational scenario` is instantiated, but it cannot progress to the `accessible` state. Figure 9 shows a view of a learnflow with a `temporal` placeholder in the final `scenario`.

Figure 10 shows the allowed execution states for a `scenario` instance. When a `scenario` contains a placeholder, the scenario instance remains in the `not accessible` state.

At run-time, the teacher can fill the placeholders with activities, temporal constraints, etc. by making use of the authoring environment. When the teacher commits a change (the filling of a placeholder) the related `scenario` can progress to the `accessible` state.

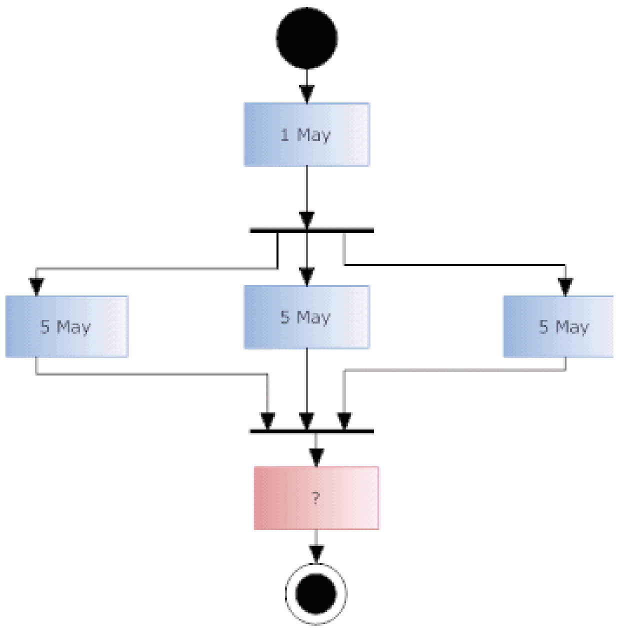

Figure 9. Temporal placeholder in the final scenario

C. *Updating of instances*

The model is the generic/abstract description of a PoEML learnflow; it contains the formal manifest of elements (`scenarios`, `goals`, `participants`, etc.) that make part of a learnflow. Every learner who starts a learnflow enacts a new instance. So, there are as many instances as participants in the learnflow.

Every learnflow instance has its own state, which depends on the state of the `goals` that the instance contains. In the same way, the state of a `goal` depends on the state of its input and output constraints, as well as on its dependent sub-`goals`.

When a teacher commits a change in the learnflow model, every learnflow instance has to be re-evaluated from root to leaves in order to update its state.

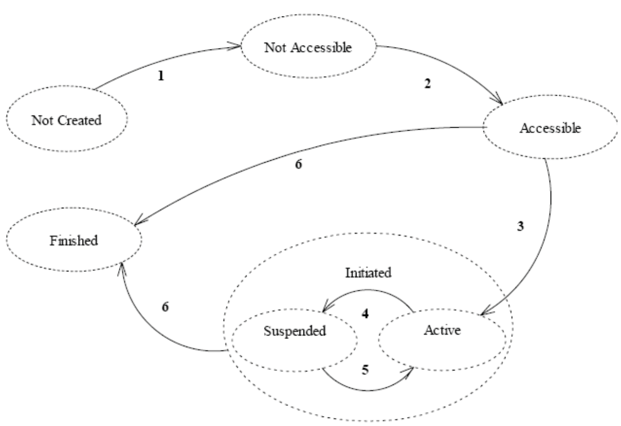

Figure 10. Execution states of a `scenario` instance

V. THE MOODLE EXTENSION

We have developed a Moodle [15] extension that is composed of a new course type with three views: run-time, authoring tool, and monitoring. The focus of this paper is the authoring tool, but for its correct exposition we need to detail the run-time and monitoring views.

In current Moodle course types, there is needed just one database schema to store the course description. In our case, we need a database schema for course descriptions and another one for run-time course instances.

A. *The authoring environment*

The authoring process consists on a series of atomic operations. In the set of possible operations there are ones such as:

- Add/edit/delete a Scenario
- Add/edit/delete a Goal
- Add/edit/delete a resource/activity

Atomic changes are validated in order to assure they are consistent with the overall course design. After verifying its consistency, the atomic change is committed against the database schema that contains course descriptions. The granularity level can be set as desired: an atomic operation may be to add a new Goal with all the required fields, or may be to edit a previously created Goal and change just one field. The authoring process consisting on atomic changes presents some valuable advantages:

- Atomic changes are automatically seen by other co-authors
- There is no need for a complex consistency check like the one needed when importing a previously created manifest file that contains a full course description

The consistency check commented in the last paragraph is yet necessary for interoperability purposes. Course description follows PoEML data model. Therefore, course descriptions can be exported from their database schema into XML manifest files. Hence, a XML manifest file that contains a course description can be imported into another PoEML-compliant Learning Management System.

Several experts are able to work collaboratively on the same design. The co-authors make atomic changes in the course design, and those changes are committed against the database schema for course descriptions. The course design can be tested on-the-fly by creating a new course instance and testing it in the run-time environment. The Figure also shows that manifest files containing course descriptions can be imported and exported into the LMS Engine database.

B. *The run-time environment*

Figure 11 shows a screenshot of the run-time environment for a participant in a course. It consists on tree course views: Structural view, Scenarios tree view, Goals view, and Functional view. We start the exposition with the structural view.

When a participant is enrolled in a course, a course instance is assigned to that participant. At that time, the course structural view is displayed at the browser. The main parts of that page are the navigation bar (Ariadna's thread), the goals, the environments and the sub-scenarios.

The navigation bar or Ariadna´s thread shows at any time the aggregation level in which the participant is. The goals box shows all the goals in the current scenario. The color of each goal is an indication of its state. The possible states are: Not Proposed, Not Attemptable, Attemptable, Pending, Completed, and Failed. Each goal box can be expanded in order to see information about input/output constraints, as well as input/output parameters.

The learning resources and activities are contained into one environment box. An environment contains Moodle-native resources and activities, such as quizzes, forums, and wikis. At the bottom of the page, the sub-scenarios are displayed.

In the Functional view, the participant can see the goals state and a list of all the environments needed to accomplish each goal. Depending on the goal that the participant is working in, the environments are displayed.

The Tree view and Goals View show a map of the current state of the scenarios and goals for a certain course instance. Those two views may be helpful to see which goals have been accomplished and which ones remain pending.

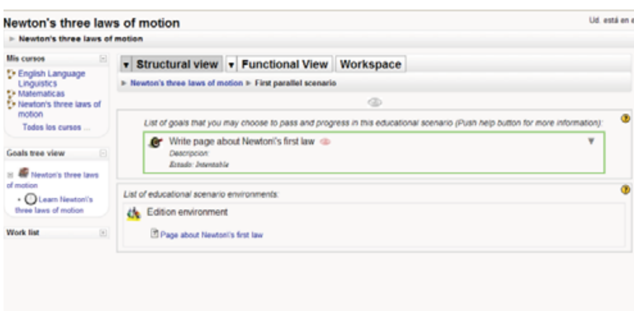

Figure 11 Screenshot of the run-time environment

C. The monitoring environment

The course monitoring feature is available for the teacher's role. This feature is divided into two different views:

- Monitoring per course element (element-driven)
- Monitoring of all elements per student (student-driven)

Figure 12 shows the monitoring of a goal. At the top of the page, we can see the possible states of the goal and the number of students per state. A histogram is used for showing that information in a graphical way. At the bottom of the page, we can see a table detailing the status of the goal for every student enrolled in the course.

Variables and data expressions can also be monitored. Variables may serve to express students' grades in a certain quiz. Data expressions serve to compose decisions that depend on the student's performance, for example, a decision that depends on the grade of a student in a quiz.

The other available view is the student-driven one. That view is suitable for monitoring the student's progression through the course itineraries.

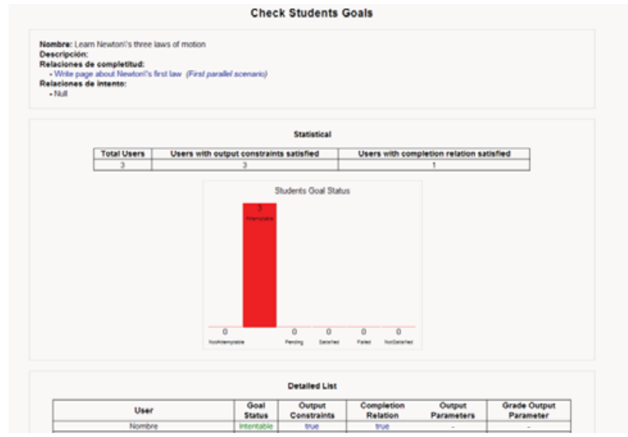

Figure 12 Screenshot of the monitoring environment

VI. IMPLEMENTATION

Figure 13 shows a diagram of the system's architecture. We detail the architecture in the following subsections:

A. *The learnflow engine (authoring, events, and information-retrieval interfaces)*

The learnflow execution engine is the core component in the e-learning system [16] [17]. The engine stores information related to educational scenarios, participants, goals, and rest of elements; and it makes the state of the system to evolute depending on produced events, both external and internal.

The execution engine is integrated into the e-learning system through a well-defined interface, which is based on Web Services, thus guaranteeing the connectivity requirements. At the same time, the presentation components must be as uncoupled as possible from the execution engine. That requirement entails to use a simple set of APIs. Scalability is an important requirement as well, because the execution engine is the central component of the system.

1) *Learnflow Models Manager*

The Learnflow Models Manager is the component that manages the learnflow models. This component maintains the versions of the models, and it also updates the models when required by an authorized user.

Communication from the exterior of the Learnflow Engine is made by making use of the Authoring Interface, which provides the needed service methods for authoring learnflow models. The Authoring Interface is used in run-time for the sake of late modeling parts of learnflow models that have been specified as placeholders during design-time.

2) Learnflow Instances Manager

The Learnflow Instances Manager is in charge of managing the learnflow instances.

Communication from the presentation module is made by making use both of the Information Retrieval Interface as well as of the Events Interface.

Presentation components are able to access the execution engine in a passive way using the Information Retrieval Interface, just to get information on educational scenarios as well as on `goals`. That information retrieval is associated to navigation through `educational scenarios`:

- Get the information related to a `educational scenario`
- Get the information related to the sub-`scenarios` of a certain `educational scenario`

In a similar way, the execution engine has to manage the events from the Events Interface, which are related to the `goals` of `educational scenarios`. A participant may generate try `goal` event, with the possible outcomes of success or failure. That event generates in the execution engine the events of instantiation of `goals` that have a completion relation with the tried `goal`.

Events generated by a participant:

- Start an `educational scenario`
- Finish an `educational scenario`
- Try a `goal`, etc.

Events generated by the execution engine:

- Instantiate an `educational scenario`
- Instantiate a `goal`
- Change the state of an `educational scenario`
- Change the state of a `goal`, etc.

An event that is external to the execution engine, such as the access to an `educational scenario`, may trigger several events that are internal to the execution engine, such as the instantiation of its sub-`scenarios`. At the same time, it is imposed one restriction: the sub-`scenarios` have to contain a `goal` in the `proposed` state. That run-time behavior can be supported with Event-Condition-Action rules [18]:

- Event: a participant accesses a `educational scenario`
- Condition: the sub-`scenario` must contain at least one `goal` in the `proposed` state
- Action: to instantiate the sub-`scenario`

In summary, the interaction between presentation components and the Learnflow Instances Manager may be passive information retrieval as well as the communication of events generated by participants.

B. The middleware layer

In order to make Web Services accessible from presentation modules we make use of the functionalities provided by a SOAP [19] engine. Thus, presentation modules have an uncoupled interaction with the learnflow execution engine.

The functionality that the execution engine provides is published to a WSDL file. The service methods are for the passive information retrieval as well as for the communication of events generated by participants.

C. Presentation modules

The presentation component is composed of three subcomponents, in accordance with the provided functionality. Hence, there are three views: authoring, monitoring, and delivering.

The authoring process consists on a series of atomic operations (in case of a ‘big’ commit, it can always be decomposed into atomic operations). In the set of allowed operations there are ones such as: add/edit/delete a `scenario`, add/edit/delete a `goal`, and add/edit/delete a `tool`.

Atomic changes are validated in order to assure that they are consistent with the overall learnflow model. After verifying its consistency, the atomic change is committed against the database schema that contains learnflow models. The authoring process consisting on atomic changes presents some valuable advantages:

- Atomic changes are automatically seen by other co-authors
- There is no need for a complex consistency check like the one needed when importing a previously created PoEML manifest file that contains a full course description

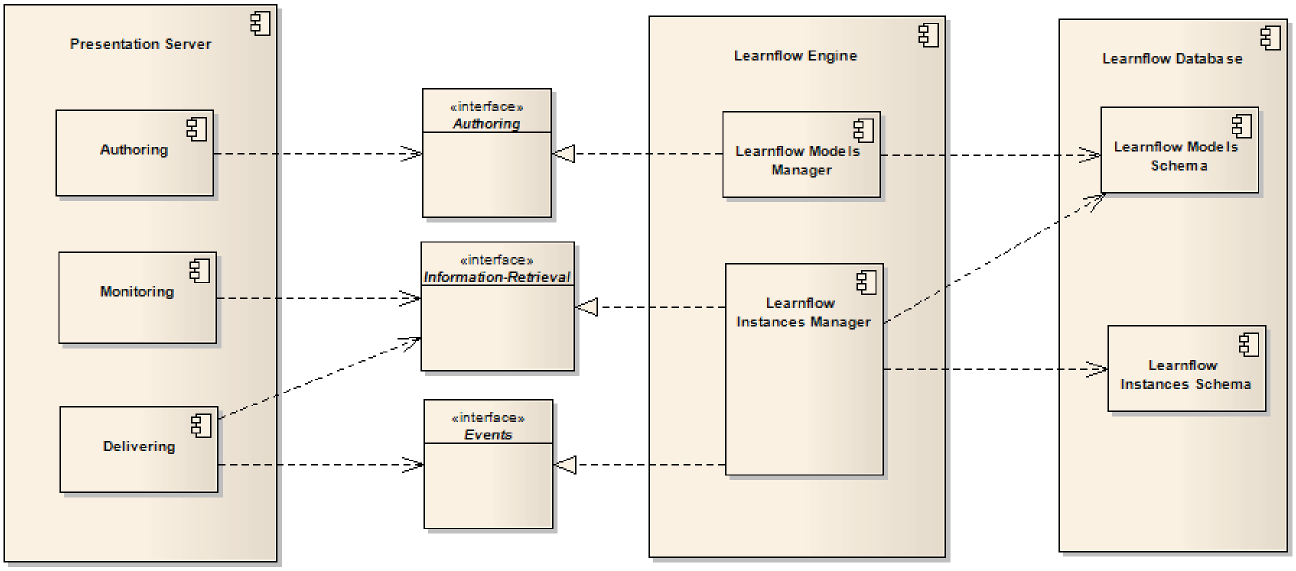

Figure 13. UML diagram of the system architecture

VII. CONCLUSIONS AND FUTURE WORK

With the PoEML-based conceptual framework described in the past sections, and the software architecture that supports it, it is enabled a kind of adaptation known as late modeling. Late modeling allows for leaving some parts of a UoL model unspecified in design-time, in order to be modeled once the learnflow is enacted, that is, during run-time.

The aspect-orientation of the PoEML language is crucial for supporting the positioning of aspect-oriented placeholders in the UoL model, thus enabling an aspect-oriented approach to late modeling.

PoEML supports well a type of adaptation based on the EML meta-model known as advanced modeling. Advanced modeling allows for considering different alternatives in the learnflow execution, known as learning paths, which are modeled during design-time.

The combination of advanced modeling and late modeling enables a high degree of adaptation, since the possibility of defining several learning paths is enhanced with the possibility of modeling parts of those learning paths during run-time.

Our future researching line is focused in the support of the adaptation types that are centered in the run-time environment: instance adaptation and type adaptation. We are currently working on providing PoEML with an execution semantics that allows for changing instances during run-time.

ACKNOWLEDGMENT

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MADAR Learning:
An interoperable environment for E&M learning

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Abstract- The rapid development we have been witnessing for some decades has placed digital information and computer networks at the core of most components of professional and individual life. Learning is one of the crucial fields of activity that have benefited from such technological development. During the last decade, integration of ICT gave birth to what is now called E-learning. The trend towards mobile technologies led to M-learning at the beginning of the current decade. The happening of these two learning environments has raised several research interrogations that revolve around the need to tap the progress by each one of these two environments for the benefit of the other. Our research group deals with this issue too. Coexistence between E and M learning has brought about the need for interoperability, which involves maximum use of technological breakthroughs in both environments and makes it, therefore, possible to build up an educational heritage, regardless of the technological learning tools used. We try to present our approach to create an E&M learning continuum.

Key words: E-learning, M-learning, pedagogy, mobile technologies, MADAR learning, interoperability, standard, IMS LD, adapting standards, modular architecture.

I. Introduction

Learning has always been a fertile ground for research aiming to facilitate access to information and content sharing, so as to provide knowledge, know-how and self management
skills. To this end, researchers involved in learning have striven to tap technological innovation for the benefit of learning.

The rapid development we have been witnessing for some decades has placed digital information and computer networks at the core of most components of professional and individual life. Learning is one of the crucial fields of activity that have benefited from such technological development. During the last decade, integration of ICT gave birth to E-learning. The trend towards mobile technologies led to M-learning at the beginning of the current decade.

The coexistence of these two learning environments, that though they use different technologies, they share the same subject of knowledge and pedagogical approaches, induces a fundamental question concerning how to build E and M learning continuum.

Our research revolves mainly around this question. We are dedicating this article to present our vision of creating the E & M learning continuum. To target this goal, several questions arise: what are the common points between these two environments? What are the different needs behind the exchange and the communication between them? How these needs can be satisfied?

To begin with, we will present the reasons behind creating an M & E learning continuum from a pedagogic and a technologic point of view. We are going to identify, at second place, the different needs' levels of exchanges and communication between these environments. Finally, we will suggest a comprehensive and a general vision of the above mentioned continuum that we name MADAR Learning.

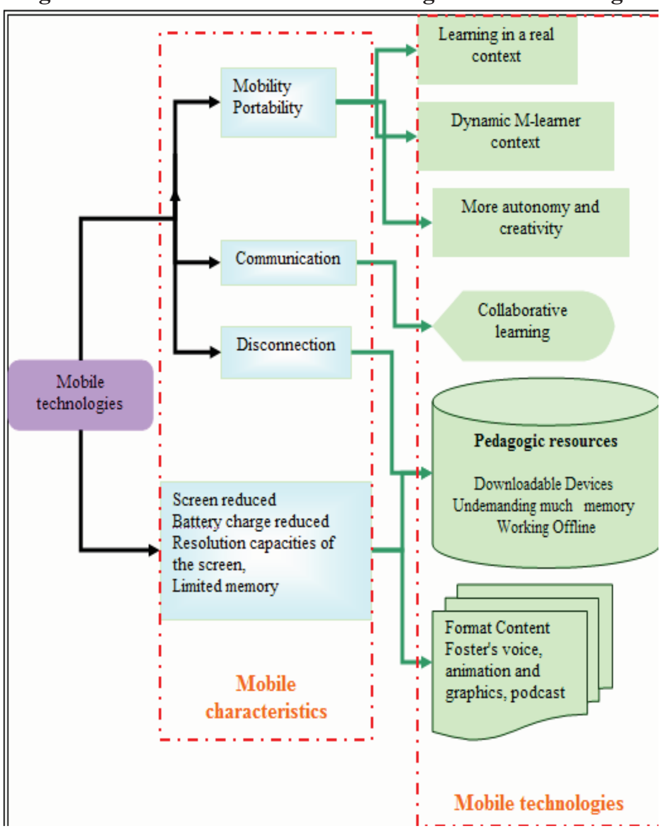
II. Why an M & E Learning continuum ?

A. Pedagogic common points

M-learning and E-learning are both distance learning environments and have, evidently, common features stemming from their context which the aim is their raison of existence . It is thus obvious that these two learning environments share the objects of knowledge that are primarily pedagogic content and support services. In fact, independently of the technological environment, the main actors in a learning situation are: The learner, the teacher, the tutor and the administrator. The process of E-learning will remain the same because it does not depend on the technology used. Consequently, the learning content, the profiles of learners and the E-learning services such as personalization, adaptation, tutoring and administrative management of training sessions are part of the M-learning.

As for the transmission mode, it can be in real time or deferred in both the E-learning and the M-learning. The existence of a virtual environment as a platform for the learning services' provision is essential to allow each actor to perform his/her functions: trainings' monitoring, interactions between different actors and the training administration management. Spaces of discussions on the Web (blogs, wikis, discussion forums, chat and email) are also the same. Thanks to the traceability provided by these tools, they currently represent a learning platform par excellence. The adoption of pedagogic approaches, appropriate to learning pedagogic contexts' objectives, constitutes also a common component of the two learning environments. Currently, several studies have proved the positive impact of classic technology and mobile technology on the learning process. Indeed, in these technologies, a collaborative learning centered on the learner is favored, and that is based primarily on the constructivist pedagogic approach and its successors (socio-constructivist and situational or contextual learning).

Figure N : 1 effects of mobile technologies on M-learning



We can conclude that the components forming a system for managing learning are the foundation of any learning regardless of the technologies used.

B. Technological differences

If the E & M learning share all pedagogic aspects of learning, they use, however, different technologies that influence the learning environment. Indeed, the use of mobile technologies has expanded, in our point view, learning opportunities and imposed new constraints [3] as illustrated in figure N°. 1.

To sum up, we can say that the M-learning can be considered as a new brick that can be added to the strengths of E-learning. Both environments, therefore, need to collaborate so as to guarantee coexistence.

However, we should take into account the specificities of M-learning. That is to say, to consider the parameters of mobile technologies in the adaptation of learning services and E-learning standards and platforms to be able to meet the specificities of M-learning in terms of: mobility, dynamic context of the learner, technical constraints of mobile devices and periods of disconnection.

The collaboration between the E and M learning can be fragmented into several levels (where each level includes the previous level), namely [1]:

- The communication: simple exchange of data;
- The cooperation: Seeking to target a common goal which is the raison d'être of the learning environment that includes the M & E learning;
- The integration: transparent belonging to a same entity. At this level of collaboration, the exchange of data, the sharing of tasks and the going after a common goal, are inherent since environments are integrated within the same learning environment (virtual or real).

To ensure this integration, we are faced by interoperability needs between E & M learning. What is interoperability between E & M Learning? What are the different levels involved? The following paragraphs are an attempt to answer such questions.

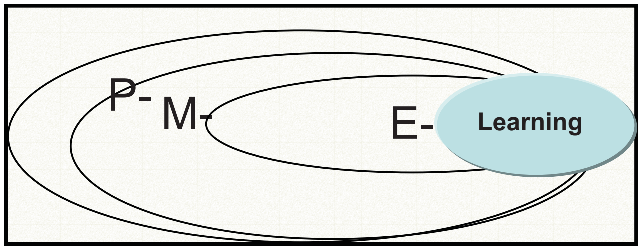
III. Interoperability at three levels for a real M & E learning continuum.

According to IEEE standard computer glossaries (1990), interoperability is the ability of two (or more) systems or components to exchange information and to use the information exchanged.

In projecting that definition in the field of distance learning through conventional and mobile technologies, interoperability involves securing communication and sharing of data, services and learning activities regardless of the development environments and instruments involved.

We have identified [7] three levels of interoperability, namely: lexical, organizational and technological.

Figure N ° 2 : MADAR learning: an overview



A. Semantic Interoperability

The content exchanged in such an environment is extremely important meaning wise, as it is designed to meet specific pedagogical objectives. Semantic Interoperability meets such a requirement. It consists in exchanging and reusing not only contents, but their meaning too.

B. Organizational interoperability

Interoperability between E & M learning is also of an organizational nature. This level corresponds to the need to capitalize on knowledge and past experience in E-learning and use them in M-Learning, in particular, as well as in future learning environments resulting from constant technological progress.

C. Technological interoperability

E & M learning environments require technological interoperability. Indeed, an independent technological environment is needed to support the technologies used by learners, so as to ensure reuse, exchange and communication of learning data, services, activities or processes.

The strategies envisaged to meet interoperability requirements include: the use of standards or families of communicating standards, the external mediator approach acting as an interpreter among components; and the use of a common communication language between modules.

The issue of interoperability between E & M learning is no exception to these rules. Solving it involves mainly: the use of standardization, along with an external mediator and common communication protocols; availing deployment environments that enable portability and mobility functions; suggesting a learning architecture that recognizes M-Learning specificities and takes advantage of E-Learning developments; and, finally, modeling distance learning scenarios in the E&M Learning environment.

In the next section we present our MADAR learning approach that seeks to respond to different levels of interoperability.

IV. MADAR Learning approach for an interoperable E & M learning environment

A. MADAR learning: an overview

MADAR learning is an acronym for 'Mobile ADaptable ARchitecture learning. This is a learning architecture adaptable to mobile technological environments [08 ICL architecture]. It may form the nucleus of an extensible architecture for future technological environments. MADAR means in Arabic trajectory. In the solar system, the course of stars tracks "MADAR" whose perimeter evolve from one year to another. Similarly, MADAR learning tracks, within our team, a continuous evolution stemming from a consecutive integration of advanced technological devices in the field of learning as illustrated in the following figure.

The aim of our approach is to create a core of services, activities and pedagogic content that will serve to create an exploitable educational heritage via various existing and future technologies.

Besides, MADAR learning suggests a management of interactions between the various existing services and the ones specific to the M-learning. However it remains extensible and open to new learning environments, namely the P-learning. That is to say, our approach targets the capitalization of the know and the know-how in the area of learning to meet the needs of three levels of interoperability between M & E learning, at first place, and foreseen learning environments that will emerge in the future (P-learning and others).

B. Pedagogy : the core of MADAR learning

Since the sixties, researches in the field of pedagogic learning approaches have witnessed an extraordinary evolution, ranging from a transmissive learning to a learner-centered pedagogy.

The constructivist approach constitutes the foundation on the basis of which many other approaches, favoring collaborative and contextual work, have emerged.

All the approaches that have emerged tend to provide an appropriate learning to the learner context, while taking into account his/her physical environment and his/her own knowledge. However, in a class environment, it is difficult or even impossible to provide individualized training (depending on the needs of each individual).

Furthermore, it is difficult to create working groups and manage collaboration within the same classroom. Moreover, it is not always possible to implement the theoretical knowledge in a real context for different reasons, namely:

The remoteness of the areas of practice from the learning institutions, the difficulty of making simulations in artificial laboratories, time constraints (practice is time consuming) etc…

Moreover, it is difficult to manage learners' autonomy in the classroom in the sense that the pace of some learners might create psychological weakness problems for the others. In addition, it is impossible for a teacher to follow different rhythms and get adapted to them during a session in the classroom environment. Because of these constraints and being aware of the benefits of ICT and mobile technologies, we suggest in our approach, MADAR learning, a collaborative learning based on the socio-constructivist approach and a contextualized learning based on situational learning [5]

C. Adaptation of E-learning standard for M-learning

The communication and the reuse of content (data, services and activities), in their original senses, are crucial to ensure the success of pedagogic objectives.

The interest in this aspect of interoperability in distance learning is thus legitimate, it emanates from its raison d'être which is the transmission of the know, the know-how and savoir être. To achieve this level of interoperability, metadata are commonly used and more precisely domain' standards or ontology that link the standards of both environments. However, in the absence of specific standards for M-learning, the use of standardization is the only resort in our opinion. We have proposed adaptations of LOM and IMS LD standards in order to use them in M-learning context [2].

D. MADAR learning architecture: The layered model

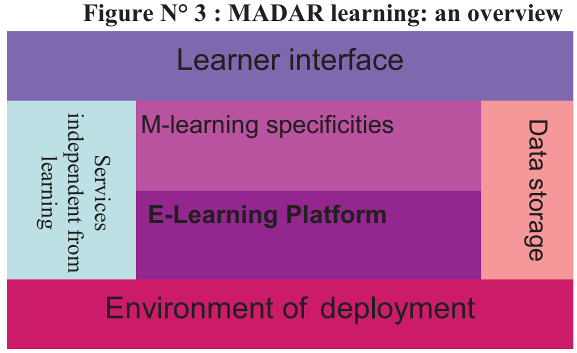
1. Characteristics of MADAR learning architecture

MADAR learning architecture must respond to three objectives, whose the achievement of one can be done only by the achievement of the other, namely: accessibility, adaptability and interoperability [4] . To target these objectives, MADAR learning must be: General, Generic, Open, Modular and independent from access equipment used by the actors.

- General : in the sense that architecture must be able to provide access to all E & M learning activities.
- Generic as far as it must provide a core of basic services common to evolving technological environments.
- Opened : in the sense that it must enable communication, exchange and exploitation of learning content, regardless of their environments of development. To achieve that, learning content should abide by the standards of the domain.
- Modular: as we mentioned earlier, our architecture must respond to evolving needs. To facilitate its extensibility of integrating new technologies, the partitioning into modules seems to be the fitting solution.
- Independent from the technology used by the actors: MADAR learning must provide independent services of access equipments be it used by learners, teachers and tutors or by the administrator.

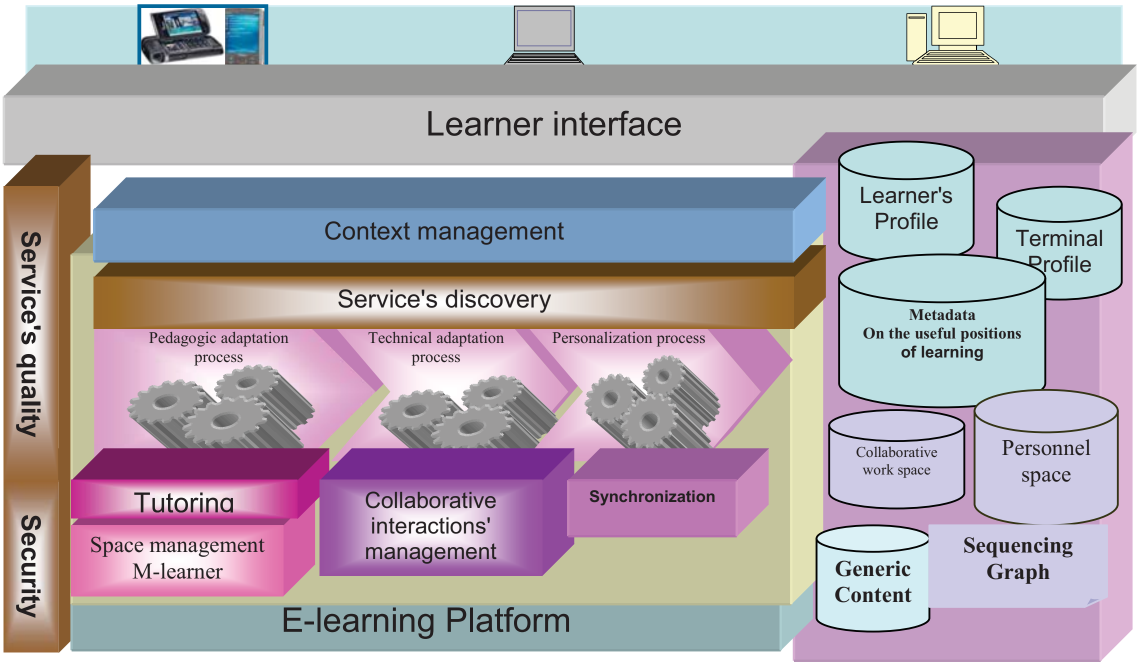
To create the continuum E & M learning we propose a layered architecture. It is based on an E-learning environment and takes into account the specificities of M-learning as well as the needs arising from the use of mobile technologies that are independent from the learning environment. MADAR learning suggests, furthermore, a deployment environment, which aims to ensure the technological level of interoperability between E & M learning. Also it provides a learner interface and a layer for data storage. In general, the functional architecture of MADAR learning is illustrated in the **figure N °3 .**

Figure N° 3 : MADAR learning: an overview



Most services of this architecture have been described in [4]. We limit ourselves in this paper to represent the layered model illustrated in figure N ° 4.

Figure N ° 4 : MADAR learning: The layered model



E. Evironment of MADAR learning deployment

The development of a technological environment conducive to the exchange, reuse of and communication between ELearning and M-Learning are extremely important elementsfor the sustainability of pedagogical materials. In this article, an attempt was made to reach technological interoperability through a deployment environment that recognizes the limitations of mobile terminals and wireless networks, while making the best use of new opportunities offered by these mobile learning technologies. It is therefore proposed that learning activities be presented as web-based services, KSOAP being strongly recommended for use with mobile devices. Taking into account disconnection periods, we have suggested the use of MOM for communications to avoid loss of messages. [3]

V. Conclusion

To achieve interoperability between E-learning and M-learning, we identified three levels of interoperability - semantic, organizational and technological - that respectively meet communication, collaboration and reutilization requirements.

To meet these levels of interoperability we suggested a general architecture MADAR learning which is layer based, modular, general, generic and open. We have also proposed technological deployment environment in order to take into account limited characteristics of small devices. So we opted for Web services combined with MOM in order to take into account the limited capabilities of mobile devices and disconnection periods. And to validate our proposal, we put in place a prototype enabling the user to avail a Web service without losing data, even disconnection happens. The use of KSOAP protocol allowed us to accommodate the limited capabilities of mobile devices. To be able to deploy the prototype, we chose to use open source software. This led us to select Jboss as an application server, and Java technology for learners. We also used Sun's WTK 2.5.2. emulators.

Based on our approach, we do not seek a restrained solution to E-learning and M-learning. On the contrary, we wish it to be open to possible future learning environments. In this vein, we suggested the principle of service encapsulation, whereby any service provided by an environment is to be used in subsequent learning environments, besides the very specificities of the latter. This principle offers the advantage of allowing extension of MADAR learning principle to other learning environments

Acknowledgment

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Session 10B Area 3: Specific Engineering Disciplines - Proffesional Developments

ESA Hands-on Space Education Project Activities for University Students: Attracting and Training the Next Generation of Space Engineers

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A competitive collaborative learning experience in chemical plant design

Galán, Santos
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Introducing Project Management Theory into a Capstone Design Sequence

McIntyre, Michael; Wilson, Stacy
Western Kentucky University (United States of America)

Information Technology in Logistics: Teaching Experiences, Infrastructure and Technologies

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ESA Hands-on Space Education Project Activities for University Students: Attracting and Training the Next Generation of Space Engineers

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Abstract—**ESA provides numerous opportunities for university students from ESA Member and Cooperating States to gain practical hands-on engineering experience on real space projects. These opportunities cover a broad spectrum of flight project activities ranging from student experiment payloads on microgravity platforms, atmospheric balloons, and sub-orbital sounding rockets to instruments and small platforms for Earth and Moon orbiting satellites. The education satellite projects range in size from pico-satellites to mini-satellites and are complemented by a global network of education institution and radio amateur ground stations. This paper describes the hands-on space engineering education programme and its setup, the engineering education methods, and the knowledge/skills transferred to the students, in addition to summary technical information on the projects concerned.**

Keywords-space; engineering; education; projects; student satellites.

I. Introduction

The ESA Education Office was established in 1998 with the purpose of motivating young people to study Science, Engineering and Technology subjects and ensuring a qualified workforce for ESA and the European space sector in the future. In achieving this, the ESA Education Office set up a hands-on space engineering education programme comprising a number of different projects underpinned by the principle that students learn engineering skills most effectively by application of their theoretical knowledge to the complete engineering process, from requirements and design, through developing, manufacturing and testing their product, to later flying it in a suitable operational environment in order to analyse the flight data for valuable lessons learned. For space engineering education, the ultimate operational environment is orbital flight (often low Earth orbit), but also sub-orbital flight has proven to be a useful learning ground for many students.

By participating in these projects, students gain the technical/programmatic knowledge and practical skills necessary for entering into the space engineering workforce, and immediately making a solid contribution to the European space programme, thus underpinning and building upon European capabilities in the space domain. The product of these projects is a set of qualified, fully trained engineers covering not only specialist technical disciplines in space engineering, such as structural, thermal, avionics, instrument, propulsion, and ground segment, but also systems engineers capable of developing complete satellites from end to end.

Since ESA hands-on space project activities began in the mid-1990's with the first student parabolic flight campaign, through the completion of three student satellite projects, to present day activities, it is estimated that over 3,600 students distributed over 22 ESA Member and Cooperating States have benefited from it. In implementing the programme, the ESA Education Office works closely with a wide network of engineering faculties in universities across Europe, with space industry companies and with ESA technical experts to ensure that supervision, seniority guidance, mentoring and knowledge transfer is provided to the participating students by experienced professionals. In this context, ESA Education Office, with its partners, also provides the necessary collaboration tools, software, facilities, independent technical reviews, workshops, and internships sponsorship to enable an effective working and learning environment. Crucially, launch opportunities are also provided by ESA in order to actually fly the student-built systems, thus giving high motivation and important post-mission learning experiences.

Past education satellite projects were the SSETI Express micro-satellite designed, built and tested by students, and launched into Low Earth Orbit (LEO) on a Russian Cosmos rocket in 2005; and the first and second Young Engineers Satellites (the latter being an in-orbit demonstration of space tether technology, which was carried on the ESA Foton-M3 microgravity mission in 2007). Ongoing student satellite projects include the ESEO (European Student Earth Orbiter) micro-satellite and the ESMO (European Student Earth Orbiter) mini-spacecraft, both currently under design and development by university students together with industrial prime contractors, and due for launch in 2012 and 2013 respectively. In addition, 9 university-developed "CubeSat" pico-satellites have been selected for launch on Europe's new small launch vehicle, Vega, in 2010. In support of future education satellite missions, the ESA Education Office is leading an international project called GENSO (Global Education Network for Satellite Operations) to establish a world-wide network of university and radio amateur ground stations in order to greatly increase communications coverage. The network commenced early operations during 2009.

Student experiments are developed and flown on a variety of platforms in order to encourage scientific research by students in subjects such as microgravity effects, atmospheric physics and technology demonstration. These platforms include the REXUS sounding rockets and BEXUS stratospheric balloons launched from Esrange in Sweden in collaboration with Swedish National Space Board and the German space agency, and the Airbus A300 Zero-G parabolic aircraft used for the Fly Your Thesis project. These platforms are flown on an annual basis, giving rise to frequent opportunities offered to students.

II. Description of Hands-on Projects

A. European Student Moon Orbiter (ESMO) mini-satellite

ESMO is a mini-satellite mission to be designed, developed, built, tested and operated by students under the guidance and supervision of an industrial prime contractor, with the goal to fully prepare a well qualified workforce for performing challenging future ESA missions in the next decades [1]. Its mission objectives are: to launch the first lunar spacecraft to be designed, built and operated by students across ESA Member States and ESA Cooperating States; to place and operate the spacecraft in a lunar orbit; to acquire images of the Moon from a stable lunar orbit and transmit them back to Earth for education outreach purposes; and to perform new measurements relevant to advanced technology demonstration, lunar science and exploration. In order to achieve these objectives, a miniaturised payload would perform measurements in lunar orbit over a six-month period.

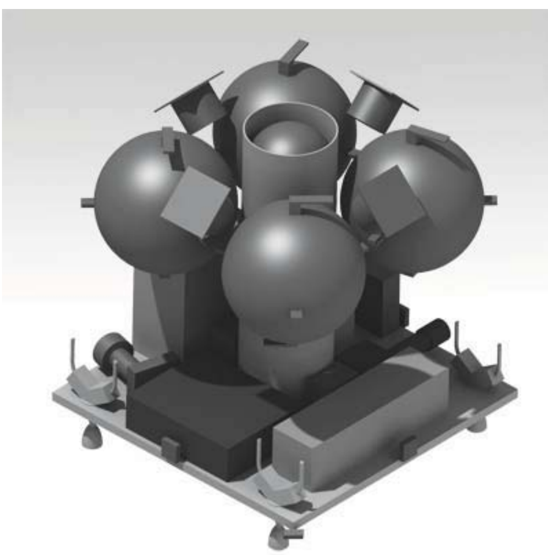

Fig. 1: Interior view of the ESMO mini-satellite (size of 80 cm on a side) showing propellants tanks and other equipment

The core payload is a 2.5 kg narrow angle camera for optical imaging of specific locations on the lunar surface upon request from schools. This will be operated from a highly eccentric lunar polar orbit similar to SMART-1. Other payloads being studied are a small radar payload, a radiation monitor, a 2.5 kg passive microwave radiometer (temperature of the regolith a few metres below the surface), and a telecommunication experiment to test a lunar internet protocol. All may be operated from the same orbit as the camera.

ESMO is planned to be launched into a Geostationary Transfer Orbit (GTO) in the 2013/2014 timeframe, as an auxiliary or secondary payload. The launcher is to be confirmed, but the spacecraft design is required to be compatible with a number of launch vehicles in order to allow flexibility in launch options. Over a period of three months, an onboard liquid bipropellant propulsion system will be used to transfer the spacecraft from GTO to its operational lunar orbit via the Sun-Earth L1 Lagrange point in order to save propellant.

The ESMO spacecraft (see Fig. 1) is designed to have a mass at launch of 190 kg (including propellant) and cubic dimensions of less than 80 cm on a side. It is fully 3-axis stabilized in attitude control and has an end of life power generation of 120 W from the solar panels mounted to the spacecraft body. Communication between the spacecraft and ground stations is performed at S-band frequencies for transfer of commands and telemetry/payload data to/from the mission control centre. Ground stations are located in Malindi, Kenya (10m antenna), Raisting, Germany (30 m), Villafranca, Spain (15m) for nominal operations. Additional stations in Perth/Kourou are envisaged to support the Launch and Early Operations Phase and mission-critical periods such as major spacecraft manoeuvres (e.g. Earth escape, lunar orbit insertion).

The project successfully completed a one-year Phase A Feasibility Study and passed its Phase A Review at a workshop in ESTEC in December 2007.

Surrey Satellite Technology Limited (SSTL), as System Prime Contractor, is managing the ESMO project for the ESA Education Office and providing considerable system-level and specialist technical support to the university student teams during the implementation of the project until launch and early operations. Some 200 students from 17 universities in 10 countries are currently participating in the project. Student work on the first part of the preliminary design (Phase B1) has progressed through 2008 and 2009. The ESMO Phase B2/C/D/E1 contract for the development and qualification of the complete system commenced in October 2009. Contractual relationships are to be put in place between the prime and the universities in order to establish academic supervisors as formal points of contact and local supervisors of the student teams for the purposes of assuring continuity and delivery. Universities are provided with funding for their participation.

The students are expected to provide most of the spacecraft subsystems, payload and ground segment systems under supervision by their universities and the prime contractor as part of their academic studies. The students obtain hands-on training and knowledge transfer by technical experts during internships, in addition to using facilities at SSTL for spacecraft assembly, integration and testing. Flight spare hardware, on-board micro-processor cores, and software is also provided by ESA to the universities where justified to lower project cost and risk.

B. European Student Earth Orbiter (ESEO) micro-satellite

The European Student Earth Orbiter (ESEO) is a micro-satellite mission to Low Earth Orbit. It is being designed, developed, integrated, and tested by European university students as part of their academic studies at university. The education objective of the ESEO project is to provide students with valuable hands-on space project experience in order to prepare a well qualified space engineering workforce for deployment on near-term space projects. The ESEO satellite will orbit the Earth taking pictures for outreach purposes, measuring radiation levels and testing technologies for future education satellite missions.

ESEO is a sub-100 kg micro-satellite (see Fig. 2) currently due for launch into low Earth orbit (LEO) as a secondary payload in 2012. To achieve its mission objectives, ESEO will carry a narrow angle camera for taking images of the Earth. A Tritel-S 3-axis dosimeter will measure the accumulated radiation dose in low Earth orbit, and a Langmuir probe will measure the instantaneous plasma environment. ESEO will also test technologies in orbit, for example, a reaction wheel, and a star tracker developed by students that will be space-qualified for later use on ESMO.

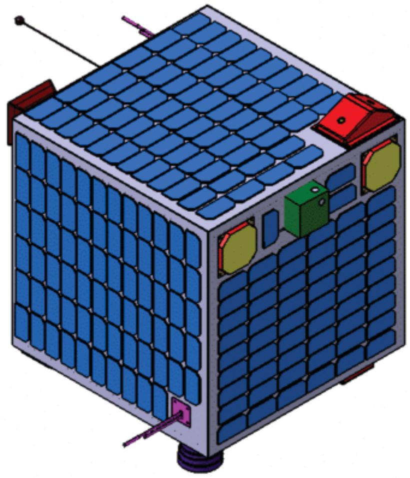

Fig. 2: Exterior view of ESEO micro-satellite (Warsaw University of Technology)

The exact launch opportunity has yet to be confirmed, although ESEO has been selected for launch with the first of the VEGA VERTA flights. However, the design aims at preserving adaptability to other launch vehicles. In LEO the spacecraft will perform its payload operations over a period of six months, with the possibility for mission extension. The orbit will be Sun Synchronous, and the remaining orbit parameters (maximum altitude < 600 km) will be selected to ensure that re-entry occurs within 25 years due to natural atmospheric drag, thus complying with the European space debris code of conduct. The ESEO satellite, as with ESMO, has 3-axis attitude stabilization (principally pointing the camera at Earth) and <100 W of power generation from the solar panels. Communication with ground is provided by an S-band transponder with also an additional transponder provided by AMSAT for communication at amateur frequencies.

As with the ESMO project, an Industrial System Prime Contractor (Carlo Gavazzi Space, CGS, Milan, Italy) is managing the ESEO project and in coordination with the ESA Education Office. They provide system-level and specialist technical support to the university student teams during the execution of the project. The students obtain training and benefit from access to the CGS and ESA in-house expertise, and can use Industry and ESTEC facilities for spacecraft assembly, integration and testing. The student teams are expected to provide most of the spacecraft subsystems, payload and ground segment systems (mission control centre, ground stations) in coordination with their universities and the prime contractor in order to deliver their elements of the mission as part of their academic studies.

The project is currently in Phase B2 (preliminary design activities in order to define the complete system down to component-level), and has recently successfully passed the Mission Definition Review and System Requirements Review during 2009. At the present time about 100 students are actively involved from 13 Universities across all Europe making preparations for the Preliminary Design Review by ESA experts in 2010.

C. CubeSat nano-satellites

A CubeSat (see Fig. 3) is a fully operable nano-satellite developed by a university for educational purposes which measures 10 x 10 x 10 cm in cubic dimensions, weighs up to 1 kg and uses Commercial Off-The-Shelf electronic components. The CubeSat standard was defined in 1999 by Stanford University and California Polytechnic State University [2]. A CubeSat can be built for €50000–€100000 by a university, plus €25000–€50000 is needed for the launch. This very cost has made CubeSats a viable option for universities across the world. Apart from the standard satellite subsystems (power, telecommunications, attitude determination and control, onboard data handling and storage) most CubeSats carry one or two scientific instruments or a technology demonstration payload.

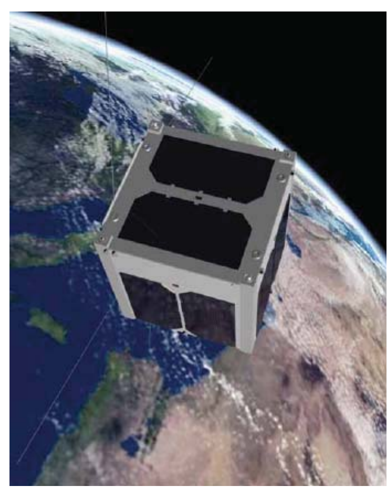

Fig. 3: Artist's impression of a Cubesat in orbit

In May 2007, ESA signed an internal inter-directorate agreement to include an educational payload on the maiden flight of Vega, ESA's new small launch vehicle which is currently under development and presently slated for launch in November 2010. This educational payload consists of nine CubeSats with two back-up CubeSats that can replace the primary satellites should they not be ready in time. The CubeSats that have been selected for the flight opportunity are given in Table 1 below.

TABLE I. UNIVERSITY CUBESATS SELECTED FOR VEGA LAUNCH

Name	University	Country	Mission
SwissCube	EPFL	Switzer-land	Air glow
Xatcobeo	Vigo	Spain	Software-defined radio; solar panel deployment
UNICube-SAT	Rome "La Sapienza"	Italy	Atmospheric neutral density measurements
Robusta	Montpellier 2	France	Radiation effects on bipolar transistors
AtmoCube	Trieste	Italy	Space weather measurements
e-st@r	Politecnico di Torino	Italy	test active 3-axis Attitude Control
OUFTI-1	Liège	Belgium	test D-STAR amateur radio protocol in space
Goliat	Bucharest	Romania	Earth imaging; space environment measure
PW-Sat	Warsaw Uni of Technology	Poland	deployable drag augmentation device

To support the selection of the CubeSats for Vega, a workshop was organised by the Education Office on 22 –24 January 2008. The workshop at ESTEC was the first of its kind at a European level and brought together almost all of the European CubeSat teams for the first time. There are now 35 teams developing CubeSats in ESA Member States and Cooperating States. A second workshop was organized in January 2009 in order to facilitate information exchange amongst this large community and to discuss possible concepts for future CubeSat missions, such as multiple satellite constellations/networks for communications/space weather.

D. Global Educational Network for Satellite Operations

As a complementary hands-on activity to CubeSats, GENSO is a planned network of over 100 small ground stations that is intended to provide global, near-continuous coverage of educational satellites in LEO (see Fig. 4). The network is being implemented under the auspices of the International Space Education Board (ISEB) with CNES, CSA, ESA, JAXA and NASA as member space agencies.

At present, a university typically builds a small satellite (e.g. a CubeSat) and launches it into low Earth orbit. It also builds, or already has available, a ground station to track the satellite and facilitate uplink/downlink telecommunications.

The period of a low Earth orbit is typically about 90 minutes, but the duration of a satellite pass over the ground station is very short and varies from approximately 10 minutes in the best case to no coverage at all for most of the orbits. When supporting only one satellite project, the ground station is not in operation 97% of the time. This is highly inefficient and often, despite onboard data storage capability, a limiting factor in mission return. Moreover, there are sometimes mission critical operations requiring uninterrupted coverage for several hours. However, the situation would dramatically improve if the satellite could be tracked by other ground stations along its ground track.

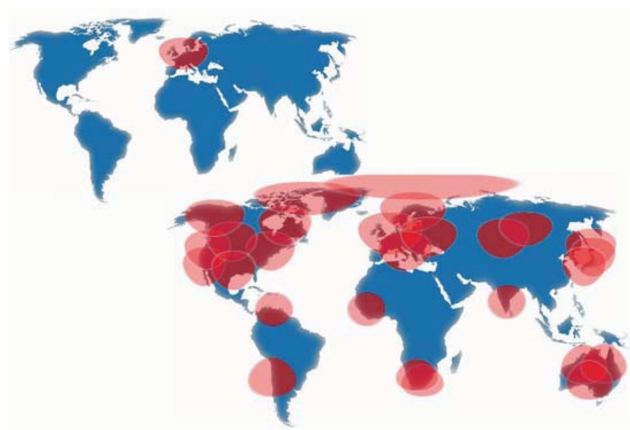

Fig. 4: Coverage of a single ground station in Europe (upper image) compared with envisaged coverage of the GENSO network (lower image)

GENSO provides an attractive solution to these limitations by linking together university/radio amateur ground stations around the world over the internet via the use of standard client software installed in the Ground Station Server (GSS), Mission Control Client (MCC) connected to a central Authentication Server (AUS). Through this network architecture (see Fig. 5) it becomes possible for an operator of an educational mission to transmit commands from its mission control centre to its satellite and receive telemetry from its satellite to its mission control centre even when the satellite is not in view of its own ground station [3].

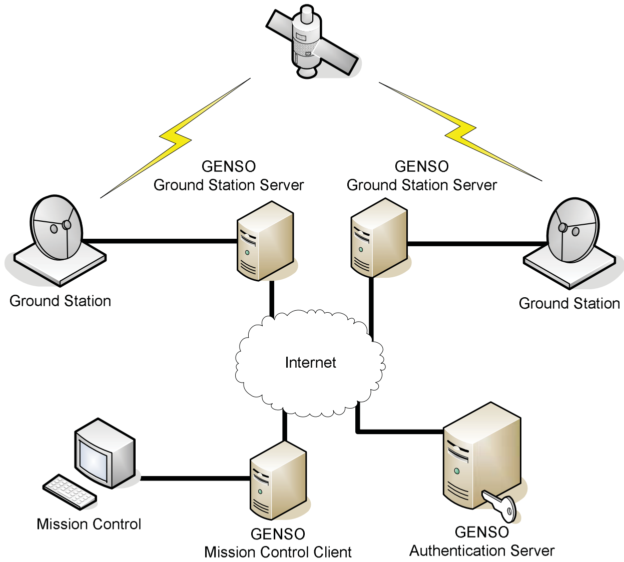

Fig. 5: GENSO network architecture

During a workshop at the University of Aalborg in November 2007, a successful proof-of-concept was demonstrated when an Authentication Server in Austria was connected to the GSS and the MCC software applications installed on the Aalborg ground station. Japanese and American hardware drivers were configured to control the ground station hardware, and telemetry was received from four student satellites – the passes were scheduled, the satellites tracked from horizon to horizon, the radio set and corrected for Doppler, and data decoded. Since then, the GSS application has been installed in five further ground stations in the UK, California and Japan to run tests for tracking satellites and automatically scheduling passes.

In parallel, two dedicated GENSO ground stations have been installed at the European Space Operations Centre (ESOC) in Darmstadt, Germany and at the International Space University (ISU) in Strasbourg. The ISU ground station was installed during August 2008. Installation of a ground station at ESTEC in the Netherlands is currently planned for 2010. These stations are used as nodes in the network but also to test new features and hardware/driver configurations.

ESA is responsible for the overall management of the GENSO project, on behalf of the ISEB. System engineering and technical support is being provided by Selex (Vega) UK under contract. The core software development teams are based at Aalborg University (Denmark), TU Vienna (Austria), Uni. Jean Monnet Paris (France), CalPoly (USA) and UNISEC (Japan). Further teams from Poznan (Poland), Politecnica de Madrid (Spain), and University of Tartu (Estonia) have joined during 2009 to support graphical user interface, scheduling, and driver developments. AMSAT UK is an integral partner in the project on ground station hardware configuration and provides the interface to the radio amateur community participation. University of Vigo (Spain) has recently been selected as the European Operations Node for GENSO to run the Authentication Server in Europe.

The GENSO software applications have been developed and tested to a first release by an international university student development team. An initial operations phase recently commenced in October 2009 with a limited number of ground stations playing an active role (<20 stations are being connected). Operational experience and requests/ideas for extended features will be fed into the ongoing development of GENSO software release 2.0, which is planned to be available in April 2010. At this time, the network will become open to all compatible education/radio amateur ground stations requesting to join through the world, aiming at the widest possible geographical distribution in order to maximize communications coverage for the benefiting satellites.

E. Sounding rockets & balloon experiments

REXUS and BEXUS are five-year programmes providing Swedish and German university students with the opportunity to launch educational experiments on sounding rockets and stratospheric balloons [4]. Three cycles are envisaged during these programmes, each beginning with a Call for Experiment Proposals and ending with the launches. A cycle comprises two rocket launches and two balloon launches. All launches are managed by Eurolaunch and take place from Esrange, near Kiruna, in northern Sweden. On each launch, half of the payload resources are available to Swedish students, the other half to German students. The flights are funded by the Swedish National Space Board (SNSB) and the Deutsches Zentrum für Luft- und Raumfahrt (DLR).

For their share of the payloads, SNSB has decided to invite students from all ESA Member States to participate in the REXUS and BEXUS campaigns. To this end, SNSB has asked the ESA Education Office to make European-wide announcements for the two annual opportunities, select the experiments, manage the interface between the selected experiment teams from European universities and SNSB and Eurolaunch/Esrange, and cover the expenses of European students to attend all of the associated activities (workshops, training week, reviews and launch campaign) [5].

In the REXUS campaign, a spin-stabilised, solid-propellant, single-stage rocket with an 'Improved Orion' motor is used, reaching an altitude of 90–100 km (see Fig. 6). The total available mass for student experiments is about 30 kg. BEXUS uses a 12SF helium balloon from Zodiac (France), which can carry a student experiment mass of 40 kg to a ceiling of 35 km. The floating phase at ceiling altitudes can last up to four hours.

The BEXUS-6/7 flight campaign took place in Kiruna, Sweden, from 3-10 October 2008. Both balloons were launched successfully on Wednesday 8 October, and the following ESA-sponsored experiments were flown:

- TimePiX@Space - Luleå University of Technology, Sweden, Charles University, Prague and Czech Technical University, Czech Republic. Detection of particles in the stratosphere using a hybrid imaging pixel detector developed at CERN [6].
- Stratospheric Census - An international team from the 'Erasmus Mundus' Space Masters course,

currently based at Luleå University of Technology, Sweden. Using innovative nanofilters combined with a strong airflow to gather dust particles from the stratosphere [7].

- Aurora – School of Aerospace Engineering, University of Rome, Italy. A study of the physical properties of the stratosphere, including temperature and magnetic field intensity [8].
- Low Cost Inertial Navigation System (Low. Co. I. N. S.) – La Sapienza University of Rome, Italy. Validation of an inertial measurement unit built with low cost sensors and components [9,10].

All experiments flown on BEXUS-6/7 were successful in collecting data and the teams have since analysed and reported on their results.

The BEXUS-8/9 flight campaign took place on 4-12 October 2009. The five ESA-sponsored experiments flown on BEXUS 9 on 11 October 2009 were:

- COMPASS (Calculating and Observing Magnetic Polar field intensity in the StratoSphere) – University of Bologna, Italy.
- CRIndIons (Measuring Cosmic Ray Induced Ionisation) – Luleå University of Technology, Sweden, Charles University, Prague and Czech Technical University, Czech Republic.
- NAVIS (North Atlantic Vessel Identification System) – Aalborg University, Denmark. A technology test for a student satellite which will receive Automatic Identification System (AIS) signals from nearby ships.
- reel.SMRT – 'Erasmus Mundus' Space Masters course, a collaboration between six European universities. An experimental gravity research platform for high altitude balloons.
- SO-hIgh – Université Catholique de Louvain-la-neuve, Belgium. A 'weather report' experiment using MEMS ((Micro-Electro-Mechanical Systems) built with Silicon-on-Insulator (SOI) technology.

Preliminary analysis indicates that the NAVIS experiment provided excellent coverage at high altitude and was successful beyond expectations. The team received and decoded 24,000 AIS packets from ships in the area. The COMPASS, SO-hIgh and CRIndIons experiments also performed well, though the reel.SMRT experiment experienced breaks in the line attached to the deployed microgravity platform and was only partially successful.

The three experiments flown in the REXUS-5/6 sounding rocket campaign on 3-11 March 2009 were:

- Nordic Ionospheric Sounding rocket Seeding Experiment (NISSE) - University of Bergen, Norway, University of Oulu, Finland & Finnish Meteorological Institute. Detection of ionized water by the EISCAT radar to study particles dynamics in the polar magnetic field [11].
- Itikka - Castor Space Club of the Tampere University Of Technology, Finland. A test of an inertial measurement unit.
- Vibration effects on biphasic fluids (VIB-BIP) - Universitat Politecnica de Catalunya, Spain. Study of the behaviour of a biphasic fluid (a liquid containing gas bubbles) in a low gravity environment under vibrations.

Unfortunately the NISSE experiment failed to function correctly. Although the rocket was clearly detected by the EISCAT radars, a malfunction in the spraying system prevented the water from leaving the spray nozzles, so no ionized water cloud was detected. The Itikka experiment was successful in acquiring acceleration data. The VIB-BIP experiment was a partial success with images of the fluid obtained, but unfortunately no vibrations in the fluid during the low gravity phase of the flight.

Fig. 6: Used in the REXUS programme, the Improved Orion M112 is an unguided solid-propellant single-stage rocket, launched from Kiruna in Sweden (SNSB)

The REXUS 7/8 launch campaign is scheduled for 22 February to 5 March 2010 when three ESA-sponsored experiments will be flown. The Call For Proposals for the next REXUS and BEXUS flights was completed during November 2009 and the selection of experiments is ongoing.

F. *Parabolic flight experiments*

Parabolic flights were proposed by ESA with the intention of fostering university student interest in microgravity research all over Europe. The Student Parabolic Flight Campaign, started in 1994, was the first hands-on activity offered by ESA. The last full ESA student campaign was held in 2006.

Thereafter, the whole programme was subjected to a thorough review, resulting in several managerial and safety recommendations for future campaigns. Following these recommendations and specific interactions between the ESA Education Office and the ESA Directorate of Human Spaceflight, a new programme concept called "Fly Your Thesis! – An Astronaut Experience" (FYT) was launched [12].

This programme offers European students the unique opportunity to design, build, and eventually fly a scientific experiment for microgravity, as part of their last year of University, i.e. for their Master or PhD thesis.

Fig. 7: Airbus A300 'Zero-G' aircraft, operated by Novespace, used by ESA for its Microgravity Research Campaigns (credit: Novespace)

Teams composed of two to four students and supported by an endorsing professor can apply, each year, by submitting a Letter of Intent to ESA Education Office. A Review Board composed of experts from the European Low Gravity Research Association (ELGRA), the ESA Directorate of Human Spaceflight and ESA Education Office pre-selects up to 20 teams who are then invited to develop detailed scientific and technical proposals with the support of an ELGRA scientific mentor. At the end of this pre-selection phase the student teams present their projects to the Review Board during a dedicated workshop held at an ESA centre. Following evaluation by the Review Board, up to four teams are finally selected to build and fly their experiments in an ESA Microgravity Research Campaign. The students accompany their experiments onboard the Airbus A300 Zero-G aircraft (see Fig. 7) for a series of three flights, each consisting of 30 parabolas of about 20s duration each. During this campaign, they work in close contact with renowned European Scientists carrying out their own research. ESA Education Office financially supports the cost of the flights, part of the hardware development, as well as necessary travel and accommodation.

For the first edition of this programme, the Review Board selected four student experiments to participate in the ESA 51st Microgravity Research Campaign which took place on 3-5 November 2009 in Bordeaux:

- *Complex* - a team of three students from the Norwegian University of Science and Technology, in Trondheim, Norway. They studied the flow birefringence of a solution of clay particles in salty water, allowing them to have a deeper understanding of the self-organisation of those small particles.
- *The Dust Side of the Force* - a team of five students from the Institute of Planetology at the University of Münster, Germany. The experiment was about the greenhouse and thermophoretic effect, which can lift particles off the ground in low gravity conditions. This effect is thought to be important in planet formation and the formation of dust storms on Mars.
- *AstEx* - a team of three students from the Open University in the United Kingdom and the University of Nice-Sophia Antipolis, France. Their experiment investigated the behaviour of granular material under shear stress, with the possibility of using their results in the design of future asteroid sample return missions.
- *ABCtr MicroG* - a team of four students from the Autonomous University of Barcelona and the Polytechnic University of Catalonia in Spain. Their experiment investigated the behaviour of particular biological agents involved in the assimilation of drugs by the human body. The results could help to improve treatments in space.

A second call for the FYT programme was launched in April 2009 and a preliminary selection of 12 student teams has been announced at the beginning of September 2009.

G. Drop tower experiments

The ESA Education office is endeavouring to extend the range of hands-on activities by developing student programmes for other microgravity ground-based platforms. This year, a new hands-on activity called "Drop Your Thesis!" (DYT) has been launched. The aim of this educational programme is to give European students access to the ZARM Drop Tower, in Bremen, in Germany. Each year one university student team will be offered the opportunity to drop, a few times, a microgravity scientific experiment as part of their Masters or PhD thesis. This facility is composed of a 146 m tall steel tube, designed as a vacuum unit, which houses all technical parts to handle the drop capsule. Below the tower, a chamber of 11 m depth contains the catapult system. The installation delivers 4.74 s of microgravity in dropping mode and 9.3 s in the catapulting mode. The first call for proposals was launched in November 2009 and a first campaign will be held in autumn 2010.

H. Large diameter centrifuge experiments

In parallel to the FYT and DYT programmes, the ESA Education Office has launched a complementary gravity-related programme called "Spin Your Thesis!" (SYT) to provide European students with access to the Large Diameter Centrifuge facility, in Noordwijk, in the Netherlands. This centrifuge has a diameter of eight meters and is composed of four arms which can support up to six gondolas (see Figure 8). In order to perform the experiments, the acceleration of the facility varies from 1 to 20 times Earth's gravity within at least

60 s. The objective of this educational programme is to have, each year, a two-week campaign with four university student experiments. The first call for proposals was made during autumn 2009 and first campaign should take place in spring 2010.

Fig. 8: Picture of the ESA Large Diameter Centrifuge (ESA)

I. CanSat activities

A CanSat is a mock 'satellite' accommodated within the volume and shape of a regular soft drink can (see Fig. 9). The CanSat concept was introduced in 1998 by Professor Robert Twiggs from Stanford University. Just like a real satellite, a CanSat consists of a 'bus' and a payload. The bus comprises the structure (the aluminium soft drink can, antenna, circuit board), power (battery), telecommunications (transmitter), onboard computer and the recovery system (parachute). The payload may consist of sensors for measuring accelerations, the ambient air temperature, pressure and humidity, a differential GPS, a camera (pictures or video), attitude determination sensors or a mini-rover.

A CanSat is launched by an amateur rocket to an altitude of 500–4000 m. Balloons have also been used as release platforms. After release from the rocket at apogee, a parachute or parafoil opens and 5–20 minutes later the CanSat makes a soft landing. The drop time, during which it transmits telemetry, is comparable to the horizon-to-horizon pass of a satellite in low Earth orbit. Their advantages are that they can be built at very low cost, typically under €1000 and can be proposed, designed, built, tested and launched in six to nine months.

The building of a CanSat usually involves participation in a competition for university and high school students. Such competitions are organised regularly in different parts of the world. The competitions are in generally two categories:

- the standard CanSats (370 g)
- the Open Class' (over 1 kg), which often includes a mini-rover.

Over the past three years, there has been growing interest amongst European countries for CanSat activities. In The Netherlands, a pilot demonstration was organised in 2007, followed by national competitions for upper secondary school students in 2008 and 2009. Further pilot competitions took place on a national level in Spain, France and Norway in 2008 and 2009 and these activities look set to continue in the future.

Fig. 9: Typical Cansat deployment with parachute (CanSat Nederland)

Based on the objectives of the ESA Education Office and its existing profile of hands-on activities, ESA's first priority for supporting CanSat activities is to encourage the set-up of activities in more of its Member States, focusing in particular on secondary schools. A workshop was held in October 2009 to brainstorm possible collaborations with the organisers of national competitions and other interested parties. Several possibilities are under consideration, including the establishment of a common website for European CanSat activities, the development of a CanSat kit and the organisation of a European-level competition.

III. ENGINEERING EDUCATION METHODS

Focusing students on real world engineering problems in the space domain, by allowing them to work hands-on to ultimately design, develop and build space-related hardware and software systems capable of functioning successfully as required in their operational environments has proven to be a very powerful engineering education tool. The 'learning by doing' approach has been underpinned and reinforced by a number of formal education methods, introduced as a result of lessons learned on the student project activities, which have led to increased success in the educational and operational/mission outcomes.

A. Mentoring by senior technical experts

Where possible within the scope of the project, the work of the students has been closely followed by a senior expert in the relevant technical field. This has been done both remotely (expert and students not co-located, communication by phone or internet) and locally (student and mentor co-located, communication largely through daily face-to-face meetings). Remote mentoring has had limited effectiveness, whereas local mentoring has proven to be highly effective in all cases. It has been most effective when students are embedded in the core system team of the project on internships. Such a daily contact with expert advice has led to strong motivation, deep understanding, high quality work output, and resulting engineering products either meeting or exceeding requirements and expectations. Quick progress is made due to mentors allowing students to explore the trade space whilst properly bounding it and guiding them towards the best solution to the problem, often based on their past experience with the appropriate rationale behind.

B. Training courses to increase practical skills

For the majority of the project activities, regular workshops are held either at ESTEC or the prime contractor (in the case of the micro-satellite projects). These are one week events where representatives from each team of students working on the particular project gather together to coordinate their interfaces/dependencies with each other, and to complete group tasks required by the project team (ESA or prime contractor) to make significant progress on project milestones. Whilst this is also an occasion for the students to meet their mentors (typically for half a day or more), additional education is given to students in the form of training courses. This has been particularly useful in increasing practical skill levels in advance of upcoming relevant project work. Courses in such areas as requirements definition, structure/electronics/thermal design & analysis techniques, and manufacturing of PCBs/cables through soldering and crimping have benefited the overall quality of workmanship achieved by the students. This is also foreseen to reduce the number of defects that need to be remedied later on, saving time and effort.

C. Immersion in the project environment

Considerable effort and investment has been made to allow students to be fully involved in the project activities, through regular contacts, meetings and internet-based tools for the exchange of key information, particularly technical data. System engineering tools are accessible to all students and capture all requirements and design data at all levels and all originators on the project. Licences for industry standard analysis tools (e.g. NASTRAN/PASTRAN for structural analysis) are provided to participating student teams in order to facilitate design decisions down to the lowest level. Furthermore, project management related aspects such as schedule, work breakdowns and task descriptions are provided at the start of the project activity (or phase of the activity) in order to give a clear path ahead to follow. A web portal is used to clarify points of uncertainty and to track tasks and project events on a continuous basis.

D. Independent reviews of design

All project activities undergo formal project reviews at key milestones in the project lifecycle, such as requirements reviews to agree on the requirements for students to follow, or preliminary or detailed design reviews to check that their designs comply with the requirements agreed. Later on in a project, post-test reviews are conducted in order to qualify the design or accept student-built flight hardware for system/platform integration. These reviews involve ESA technical experts not directly participating in the project, and have been an extremely useful learning experience for the students (as they learn more about quality standards and trying to meet those standards), as well as raising overall quality levels. It is also an important verification of their work if it passes an ESA review.

IV. Knowledge/Skills Transfer to Students

Across the different project activities, the knowledge transfer to the students varies according to the strategy of the Education Office to meet the needs of a well qualified workforce.

A. Micro-satellites

These larger projects involve tens of different universities working on different subsystems of the overall system over typically 3 or 4 years in the development cycle. Here, students gain significant specialist experience and deep insight into a particular subsystem, and learn to define and adhere to interfaces with other subsystems. This satisfies the needs to produce specialists in Europe in particular competency areas known to be in short supply in the workforce. Student system engineers are also trained and a knowledge of complex space systems is developed. However, due to the long duration, students typically only experience part of the engineering process (either design, development or manufacture/testing), and knowledge transfer between generations of students in each team is crucial. This continuity must be provided by the supervising professor locally at the university. The involvement of space industry is expected to also give students a working knowledge of how to apply and meet minimum product assurance standards.

B. Nano-satellites

Being contained within a single university and short enough in duration to have the development cycle fitting within one generation of students, these smaller projects produce specialist engineers and system engineers with a working knowledge of space systems with moderate complexity, but with stronger system engineering process and full project lifecycle understanding than the micro-satellite projects. Students appreciate a high degree of interdisciplinarity due to the vertical integration of the project team in one location, but as a result they tend not to strongly experience interface definition activities which are relevant to larger space projects. A moderate level of innovation is enabled where students can explore and demonstrate new concepts/technologies.

C. Student experiments

As these are highly focussed short-term activities where the full development cycle lasts for a year or less, they are an excellent introduction to the space project lifecycle and an opportunity to gain excellent and relevant hands-on practical skills in a less challenging flight environment than Earth orbit. These opportunities offer students the possibility to be creative in design, perform scientific/technology research and test their ideas/concepts with a specific experiment development. They still gain experience of interdisciplinarity (to a lesser extent) since structural, electronics and software engineers need to work in the same team to achieve their objectives. Engineering as well as science students benefit from these programmes, and the experience gained can lead to a career path suited to instrument/payload engineering.

D. Ground segment

The GENSO project in particular is targeted at producing the ground segment, software and operations engineers of the future workforce. Students gain knowledge in ground station networks, mission control centre functions, real-time communications links and mission planning/data exploitation activities. Whilst specific protocols are not widely used in ESA missions, the underlying principles remain the same, so the students can gain a deep understanding of the ground segment elements.

E. High school hands-on activities

These activities, with CanSats in particular, give children their first contact with the space domain and serve to attract the next generation of youngsters into engineering faculties at university where they can then build satellites and flight experiments prior to graduating and entering careers in ESA or industry. The opportunity to build, program and fly a CanSat under the supervision of their teacher, then compete against other schools to win a prize can give inspiration to children and spark their interest in space, thus leading to increased take-up in science, technology, engineering and mathematics subjects at school and an increase in the pool of potential (space) engineers.

V. CONCLUSIONS

Over 3,500 European students have been involved in the various hands-on activities announced, managed and funded by the ESA Education Office to date. They have been able to visit ESTEC and participate in workshops, project reviews, integration and test campaigns. They have prepared the required documentation according to professional standards, followed formal engineering processes and participated in communication and outreach activities. They have developed flight and ground hardware and software, benefited from the support by ESTEC/industry staff on these projects, and from detailed discussions with these experts. Throughout all these processes they have met fellow students from other European countries, learned how to work successfully as a team, and established valuable contacts at ESA and in the space industry. Several hundred Masters and PhD theses have resulted from these projects, and the active involvement in one of the projects of the Education Office has often been the first step towards a successful career in space.

VI. ACKNOWLEDGEMENTS

The ESA Education Office wishes to acknowledge the high cooperation of its international/European partners, contractors and participating universities in conducting the abovementioned education projects activities.

Furthermore, several past and present Young Graduate Trainees working in the Education Office have contributed significantly to the progress made in these hands-on projects. They are too numerous to name, but their support is well appreciated.

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A competitive collaborative learning experience in chemical plant design

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Abstract—**This paper reports on the experience of using collaborative learning techniques in a competition environment, which can be a proper approach in the traditionally highly demanding and competitive engineering courses, avoiding most of the drawbacks attributed to collaborative learning methods. The students were organized in contractor "companies" with several technical departments and a project manager, competing at every stage of the design process. The final result included some of the usual documentation of a professional basic engineering project. The results were good technically and well accepted by the students, but not all the drawbacks were removed.**

Keywords--collaborative learning; engineering course; design project; chemical engineering

I. INTRODUCTION

In recent years, the collaborative learning paradigm has been increasingly incorporated in modern engineering courses. The term collaborative learning is one of the names (e.g., cooperative learning, study groups, etc.) that encompasses a variety of learning/teaching techniques where students work together in small groups. It is frequently presented in opposition to competitive and individualistic learning, sometimes in such an enthusiastic way that forgets or even neglects [1] the benefits of the other approaches, as well as self-criticism.

Some of the advantages of this learning strategy are more comprehensive learning, lower failure and drop-out rate and a better understanding through peer discussion. Collaborative learning is said to foster creative thinking as members in a group generate new ideas, strategies, and solutions more frequently than working individually [2].

Disadvantages include (time) inefficiency, unclear hierarchical structure and unfairness in grading. Also, active resistance to collaborative methods in science and engineering courses has been reported [3].

Since the benefits of the technique have been extensively praised in the literature, in the following section we will focus on the disadvantages and false attributions that the experience described in this paper tried to avoid.

II. DRAWBACKS OF COLLABORATIVE LEARNING

One of the reasons adduced to apply collaborative learning strategies in engineering instruction is that professional engineers must interact with other engineers and professionals, requiring communication, leadership and teamwork skills that are not effectively instilled by traditional teaching techniques [4]. This is true, but the statement needs qualifying:

- Apart from pathological individuals, students have been acquiring and developing social skills since they attended the kindergarten, mainly not at the school.
- In professional life, teamwork is organized around specialized personnel with a clear hierarchy where leaders have got the authority to remedy low achievement or improper behavior. This is not the case at the university, where the students are forced to deal with potentially uncooperative members.

Working in a group requires not only social skills but also organizational and management effort, what is generally not recognized enough at grading. Even when these abilities can be taught, they are built over the knowledge of what has to be managed, so young students are not the best candidates. Also, in the extremely demanding engineering courses, the managerial effort has to be detracted from other learning activities: It is generally recognized that group work usually means covering fewer topics, what should be balanced in every case against the benefits gained.

A common negative comment from students is that not all the members spend the same amount of effort in group work but they are awarded a group mark [5]. The apologists of the collaborative learning methodology would likely answer that positive interdependence has not been achieved or that task assignment was unequal, what can be solved. Those professors would possibly understand better the students' point of view by just suggesting them to get paid (only a fraction of their salary) on a department group basis.

It is difficult to find a professor that confess it, but frequently, group work means less correction work. Finally, the author cannot forget what an instructor for collaborative learning techniques told in one seminar he attended: Collaborative learning was a necessity because of our current, less motivated and less prone to effort, students.

To summarize, collaborative learning is not the panacea: It does work for some students and it does not for others, (especially at engineering schools), and it has got advantages and disadvantages. Learning, as responsibility, is always individual and collaborative learning strategies cannot be used in a general and naïf way, but are the appropriate tool for some courses and subjects. At engineering schools, they have to be carefully tuned in order to be efficient and accepted. The experience that follows, applying a competitive orientation, tried to do it.

III. THE DESIGN PROJECT

Design projects are a classic tool in engineering teaching that induces learning through doing and where collaborative learning can be applied.

The experience this paper deals with was implemented in a Separation Processes course in parallel with the development of the common topics: distillation, column trays design, liquid-liquid extraction, leaching and crystallization. The assignment was the design of a chemical process and plant based in a (part of a) real-world project for ETBE production.

A. *Organization of the work*

The students were organized in four groups (contractor companies) of five students, each one responsible of one of the five typical departments of an engineering company: project management, process design, mechanical design (columns and heat exchangers), instrumentation and piping. The project managers were the top students as by the qualifications of the tests of the first two weeks of the course. Then they have to negotiate with the rest of students to complete the company. There was no need for the professor to intervene.

The contractors received only the design basis specification and letters from the client (the professor) asking for the development of a stage of the plant design, usually affecting mainly to only one department. At the department level, at every stage of the design the four groups competed and the best solution was adopted for all the groups, providing the same starting point for the evaluation of every department. The students applied the knowledge of the course and were provided with additional information and examples for the auxiliary tasks.

The first milestone was the process flowsheet, to be developed by the process engineering departments. It implied the design of two distillation columns with eleven components, not having information about the separation sequence. The students used for the design the standard professional process simulator Aspen Plus. This is a difficult problem and the professor provided some additional orientation via e-mail and discussion meetings. The project managers of three groups assigned their best performers to this department, probably because this one is the only task directly related to the topics taught in the conventional course and it was expected arduous. The process flowsheet with the stream table is shown in figure 1, just as an indication of its complexity.

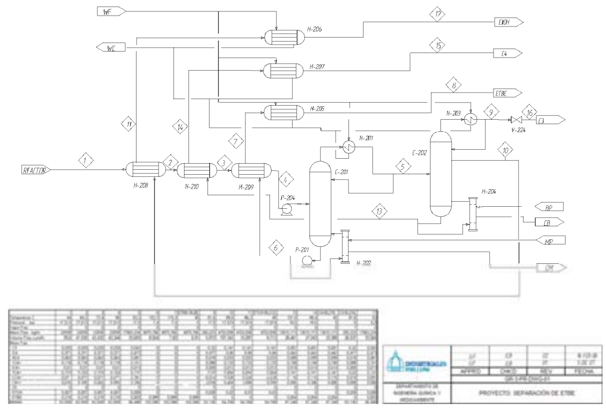

Figure 1. Process flowsheet

With the process information the rest of departments did begin their work:

- The control and instrumentation section developed an outline of the control strategy, the P&I diagrams (figure 2), the list of instruments and a preliminary study of the process safety system.
- The mechanical departments did a thermal calculation of the heat exchangers and a basic engineering design of the columns using KG-Tower, the program supplied by the company Koch-Glitsch. For every item in the list (of equipments) a specification sheet was written.
- The piping department determined de dimensions of the pipelines, drawn the plot plan and the isometric diagrams (see a sample in figure 3).

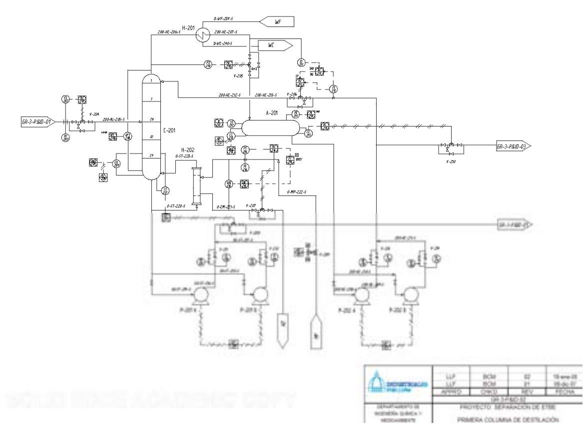

Figure 2. P & I Diagram

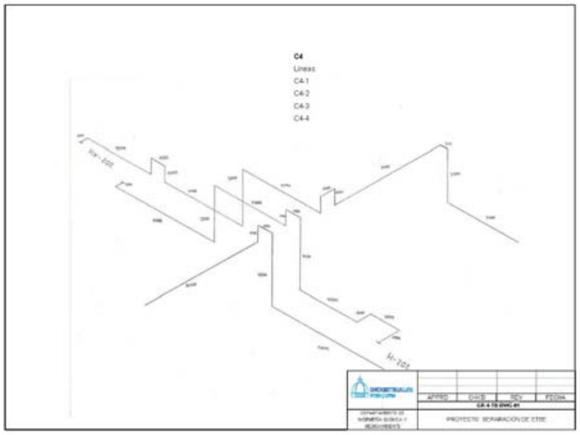

Figure 3. Piping isometric

As these tasks have to be developed almost simultaneously, there were some intermediate milestones for homogenization. The elaboration is really an integrated process were the role of the project manager, coordinating the work of his departments as well as, sometimes, the work with other groups at homogenization, was critical:

- Additional process data, as physical properties, are required for the piping and equipment design.
- The instrumentation department needs to discuss the control strategy with the process department.
- The equipment data are needed for the P&ID, the piping design and the plot plan. Note that isometric diagrams are the 3D routes of pipes in the real plant. You need to know the dimensions of the equipments and its positions in the plant.
- The piping dimensions determine the nozzle diameters of the equipment.
- Instrumentation induced connections in equipments and pipes.

Apart from the coordination function, project managers wrote an operations manual, formatted the design basis and detailed the utilities. They also collected an organized all the documents of the project.

All the documentation generated was included in a basic engineering ("black") book with around 30 documents (reports and drawings).

B. Grading policy

The general idea behind the grade structure was to avoid the drawbacks of the collaborative learning methodology, in particular the usual conflicts in groups of students that, apart from trying to learn, have to deal with the negotiations in a team where the hierarchy is diffuse or inexistent. As mentioned above, collaborative learning is generally presented as an imitation of actual professional life, but the interests and consequences of actions in the real world configure quite different scenarios.

Grading included individual and group results:

- Students that did not acted as project managers got their individual marks from the professor, their project manager and department peers at the other groups, but they only knew the final result.
- Project managers got their individual marks from the professor, their departments and project managers at other the groups, just knowing only the final result.
- The group mark was decided by the professor and a poll where all the students participated. Of course, they could not vote themselves.
- Every student got his grade by combining the group and individual marks.
- Additionally, a poll was filled by the students at the end of the project.

By letting the departments to grade the project manager and the project manager to grade the departments it was expected that a reciprocal sense of interdependency appeared, but it did not happen. The authority of the project manager was ignored several times, requiring the intervention of the professor.

IV. RESULTS

Not all the groups completed all the tasks (it was difficult) and one student abandoned in the middle of the project, but the results from the technical and instructional points of view were very good. The projects were sent to a real world international contractor company for evaluation and their comments were very positive, mentioning an "almost" professional work.

In the poll, many students answered that it was the first time that they participated in such kind of design projects, so related to professional life. That they really liked it, but they encountered the work extenuating. It was extenuating for the professor as well. The suggestion of creating a new course only for the design project was accepted and will be (hopefully) offered next year.

Some of them cited that it was unfair that there was only a winner at every stage when usually the work was quite similar, what is a criticism on the competitive orientation of the project. Actually the difference in the qualification was only extra points over the conventional mark, but they did not like the comparison.

The inclusion of incentives to keep the compromise of the students within the group was asked. Some students opined that several members of their group did not work enough, and that the mechanisms to deal with the problem were not sufficiently effective.

Almost all of the students encountered painful the change of specifications in the middle of the project (a real life problem) and asked for more information on the design methods and procedures.

The key factor for the success seems to have been the work of the project managers. The winner group was the best only at two milestones, but the final result was significantly better than the others because of the coordination and involvement of the project manager.

One of the curious issues of this learning experience is the variety of approaches and styles developed by project managers to lead their teams to achieve project goals. As it was mentioned before, project managers were the only members of the contractor groups selected applying an objective criterion. One of them, showing a surprising authoritative attitude, was partially ignored by his departments, and got a relatively bad punctuation from them. Another, using a cooperative style, was also partially ignored, but received an excellent mark from her departments. At the end, the cooperative managers got their groups develop the best projects.

V. CONCLUSIONS

The collaborative learning techniques that have been progressively incorporated in modern engineering curricula are just one of the methods that can be applied in the instruction by professors, but are not "the method". There are serious drawbacks in using collaborative learning strategies and the suspicion that some of the better results attributed to those techniques could be caused by a downgrading of the courses (at least there are less topics covered).

The experience presented in this paper tried to avoid many of the cited drawbacks, finding an appropriate case for the use of the collaborative learning methodology connected to actual professional work.

The result was good at the technical level and was well accepted by the students, but not all the goals were attained: the control of uncooperative members by the project managers using the grade policy was insufficient, and the competitive part of the design, that in part was possibly stimulating for reaching so good results, was considered unfair by some students.

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Introducing Project Management Theory into a Capstone Design Sequence

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Abstract— **The capstone design sequence in the Electrical Engineering Program at Western Kentucky University is a two semester sequence. Student teams design and execute a solution to an industrial or applied research problem during the academic year. In order to improve the capstone sequence, project management techniques have been introduced into this sequence. These techniques include acquainting students with project management theory and teaching students to manage the projects more effectively. This paper will present the basic structure of the sequences, discuss the assessment results which led to this new focus in the sequences, describe the project management techniques incorporated into the courses, and explain the impact the new emphasis has had on the capstone design sequence.**

Keywords- capstone design, senior project, project management

I. Introduction

The Electrical Engineering (EE) program within the Department of Engineering at Western Kentucky University (WKU) has a project rich curriculum. Our students take a design course each academic year that provide opportunities for completing projects. As the students mature through the curriculum the amount of work effort, design, and project size increases, until the capstone sequence of their senior year. As our student numbers have increased, the effort of managing these projects has become a difficult task for the EE faculty. To address these problems, the faculty of the EE program has utilized conventional project management techniques to create a design process to manage and asses the project teams for our senior capstone experience. The subsequent work describes the capstone design sequence our senior EE students complete. Next, the assessment data alluding to the difficulty in managing these projects is presented. In an effort to address these problems, the revitalized design process is presented with much detail. This work is completed with some concluding remarks. The utilization of this design process is new within our program. As the faculty assesses its performance in helping the student complete their projects there is room for adjustments so the process has the right balance of control and flexibility such that the students are successful.

II. Design of EE Capstone Design Sequence

Students entering their final year of study in the EE program at WKU take a two semester capstone design sequence comprised of EE 400 (EE Design IV) and EE 401 (EE Design Project). In these courses, students are placed on teams and assigned projects which include industrial and applied research projects. The students design and execute a solution to the design problem during the academic year. The courses must be taken sequentially in an academic year. The first course in the sequence is EE 400. During this course, students focus on design methodology and decision-making. The course includes ethics, professional issues, and the planning and design phase of the project culminating with oral and written reports. The objectives of this course are to further develop design skills, develop teamwork skills, learn to deal with situations in an ethical manner and write the senior project proposal.

The second course in this sequence is EE 401. This course is constructed so that the student design team will assume the primary responsibility for the completion of the project. At the end of this course, students have completed a major capstone design experience and can demonstrate their ability to design, build, and test a system to meet specified criteria. Also, students exhibit their capability to communicate their project design and results in a written format and in an oral presentation.

The design sequence has multiply opportunities for faculty to provide feedback to students regarding project progress. Mandatory status meetings occur weekly in which the design teams meet to update the faculty on the status of the project and deliverables. Prior to each progress meeting, the team must submit a status report. Also, several design reviews are scheduled for each team during the academic year. At the design reviews, the teams present the status of their project. During the design reviews, the faculty evaluates team progress toward the established project milestones. Failure to meet the milestones will affect the final grade.

III. Improving Capstone Courses Through Assessment

The WKU EE program is a relatively young program producing the first graduates in May 2004. Prior to engineering programs, WKU was home to three engineering technology programs from which the new engineering programs grew. The three engineering programs at WKU (civil, electrical, and mechanical) received ABET accreditation in 2004. The capstone design sequence is heavily assessed by the WKU EE faculty in support of the ABET Criterion 3 A-K program outcomes. [1] In fact, all eleven Criterion 3 outcomes are represented by these courses. The EE program assessment plan uses several rubrics to determine if the program outcomes are being met. Also, the faculty discusses this course heavily during the course review process in which each course taught in the curriculum is examined. The major assessment results are listed in Table 1 below.

TABLE I. SUMMARY OF ASSESSMENT RESULTS FOR CAPSTONE DESIGN COURSES

Year	Assessment Result
2004	Gantt chart developed in fall semester, project driven by timeline
2004	Students noted progress in logbook through year. Logbooks found to be ineffective.
2005	Faculty noted the need for more formal project milestones through the year
2005	Students submitted weekly progress reports rather than logbooks
2006	Established monthly design reviews as well as continued weekly meetings.
2007	Course restructured with firmer deadlines so that students had a better understanding of their final grade.
2008	Incorporated three design reviews and project deadlines into requirements
2009	Include project milestones in fall and spring semester
2009	More emphasis placed on project and time management

Over the years of offering these courses, the student performance has continued to improve. However, it is noted that students continue to struggle with setting project milestones and faculty have not given adequate intermediate feedback to students during the year. Therefore it was determined through the course assessment that more formal milestone development and appraisal should be incorporated into the courses.

IV. REVITALIZING THE CAPSTONE DESIGN SEQUENCE

In an effort to teach project management as it applies to an engineering project and to create a more manageable assessment tool to gauge project progress, the faculty of the EE program at WKU has introduced a new design process for its EE400 and EE401 design sequence. The following outline known as the *Workbook Table of Contents (WTOC)* best describes the new design process. Details of each heading will be described below.

Workbook Table of Contents

I. Project Management Plan
II. Requirements documents
III. Execution and Closing

Figure 1: Workbook Table of Contents

A. Project Management Plan

In the Project Management Plan (PMP) shown in Figure 2, the students are tasked to define all attributes of the project in an effort create a detailed statement of work. The WTOC plan should be flexible enough to meet the needs of projects of varying scope and scale. As the faculty assesses possible projects at the beginning of the academic year, it is imperative that the projects have enough creative content so that the students are able to fulfill the tasks described within the PMP. If students were not able to develop the PMP for a specific project for whatever reason, the project may not be a good fit for our sequence due to a lack of learning opportunities. An additional benefit of this PMP is to force the project sponsor to agree to a written statement of work describing the project to be completed, thus driving the development of acceptance criteria. Once this is established, the student design team and the sponsor have agreed to the components of a successful project. If for any reason during the execution of the project the deliverables change or the student design team fails to meet the stated criteria, both parties will fully understand the work did not meet the sponsor's expectations. It is often the case that due to time constraints many engineering project require that the project scope will change, or the student design team will be drawn to a different solution which results in only partial project success or project failure. Through this PMP document, all parities are focused on meeting the written goals of the project.

1) Project Requirements

To create a PMP for their projects, students are asked to complete outline items A: Project Requirements, B: Scope, and C: Project Planning, seen in Figure 2. The Project Requirements is composed of the high level project overview and definition of stakeholders. This section is the first documentation the students are asked to complete once they are assigned their projects. The students are tasked with developing an understanding of the big picture of their work as it relates to their project sponsor. It is very important that the student design team understand the impact as to why they are doing this project. There could be possible safety or financial implications that if the student design team where unaware of, the task may seem meaningless. Through this task, the students can better work to meet the organizational goals the sponsor hold very important. Also, within this section of the PMP, the student engineers determine and document all the important people that are affected by their work. Often the students will list the project sponsor and their faculty sponsor who are both working to make sure the students complete a successful project. The student will need to identify all of their team members as well.

I. Project Management Plan

- A. Project Requirements
  1. High level overview of project
  2. Identification of stakeholders
     a. Technical sponsor
     b. Faculty sponsors name
- B. Scope
  1. Product description
  2. Product acceptance criteria
  3. Project deliverables
  4. Project exclusions
  5. Project constraints
  6. Project assumptions
  7. Preliminary budget
  8. Project risks identified

9. Change control plan
10. Patent search

C. Project Planning
1. Work Breakdown Structure (WBS)
2. Activity Sequencing
3. Gantt Chart
4. Roles and responsibilities

Figure 2: Project Management Plan of WTOC

2) Scope

The next phase of the PMP after the students identify the stockholders and come to have a "big picture" view as to the "why" of their project, the students begin to develop their project scope. As can be seen in Figure 2, the Scope section contains ten items which the students generate with consultation of their project sponsor. At the beginning of the project the faculty sponsor facilitates the initial meeting between the project sponsor and the student design team. Once this has occurred, the expectation for the students to gain the information from the sponsor in a convenient, non-burdensome way is paramount. In some instances the sponsor may not be able to give information to the student engineers for all of these items. For these cases, the students are asked to make decisions and strive for agreement with their sponsor. In practice, it is common for sponsors to have unclear requirements and it is often the engineer's task to help them decide some of the finer details.

From this list of ten items some of the most important items will be described. The Project description is a lower level statement of the project, similar to that in the Project Requirements section. As stated previously a key result of the Scope is the Project Acceptance Criteria. This criterion is vital in keeping all parties focused on the goals of the project. The project deliverables are an important list of the items to be completed or created as a result of this project. This list of deliverables is used to focus the stakeholders and students on the goals of the project. Within the scope, the constraints are documented in an effort to describe what parts of the projects will not affect existing systems that interact with the project items. When completing any project, it is good practice to list the fundamental assumptions that frame the context of the engineering work. This effort is completed by listing the project assumptions. The next item in the scope is to identify and detail the project budget. In most cases the budget is a limiting item as to what tasks can be completed through the project. This PMP is flexible enough to deal with many budgetary situations.

As the student design team comes to know more about their project through the steps of developing a project scope the students are also asked to evaluate the project risks. This can be a difficult task for some projects as it may not be clear as to what risks exists for the student's success. In most cases assistance by the faculty and project sponsor helps the students in completing this task. These risks can fall within many categories. Some risks are technical risks such as a challenging design task or a nonexistent solution. There are also manufacturing risks that could impact the outcome of the project. Some projects could have human or environmental risk to be considered. For this PMP, the assessment of risk for now is open to all categories which allows for a great degree of flexibility.

It has been alluded to that over the course of an engineering project change is enviable. There are many reasons as to why there is change to the scope of a project. With this in mind, the PMP has been designed to account for this reality. The students are supplied a change control plan by their faculty sponsor. With this plan administered, the student design team and sponsors can purpose and notify one another of scope changes with the opportunity to accept and reject the proposition. Due to the complex nature of these projects, there are numerous aspects of the project that could be affected by the smallest of changes. The team can manage these changes and the affects to the project that will take place as a result.

The student design team must also understand the intellectual property landscape that exists for their project. When designing a solution to an engineering problem, it is necessary to understand what solutions are patented as to make sure there are no legal implications to possible solutions. At the same time this knowledge can help to form a valid solution that introduces new intellectual property with the possibility of new patents. Avoiding infringement is paramount when design solutions to open engineering projects.

3) Project Planning

The last component of the PMP is Project Planning, as seen in Figure 2. This section of the PMP has four items to assist in developing and documenting the time management planning stages of the project. Student engineers are introduced to some common project tools that are widely used in both industry and academia. The first of these tools is known as the Work Breakdown Structure (WBS). Through this tool, the team graphically displays and categorizes all the significant project tasks as shown in Figure 3. The creation of this document forces the students to analyze and breakdown how they will accomplish tasks to meet the documented project scope.

Robot Platform Project Work Breakdown Structure

1.0 Old Robot
1.1 Disassemble
1.2 Draw schematics of robot
1.3 Reassemble with improved wiring
1.4 Fix program glitches

2.0 New Robot
2.1 Prepare vehicle
2.1.1 Purchase vehicle
2.1.2 Remove parts on old vehicle/disassemble
2.2 Redesign robot
2.2.1 Define specs for redesign
2.2.2 Develop design
2.2.2.1 battery location
2.2.2.2 junction box location
2.2.2.3 linear actuator location

2.2.2.4 DAQ's/circuit board
2.2.2.5 onboard computer location
2.2.3 determine current component list
2.2.4 order components
2.2.5 mechanical components
2.2.5.1 draw new components
2.2.5.2 order components
2.2.6 electrical wiring plan/ power budget
2.2.7 circuit boards
2.2.7.1 draw circuit boards
2.2.7.2 order circuit boards
2.2.7.3 build circuit boards
2.2.8 refine and modify software
2.3 build robot
2.3.1 steering, starting, stopping
2.3.2 electric components
2.3.3 power
2.3.4 software integration
2.4 testing

Figure 3: Sample Work Breakdown Structure

From this list of tasks, the team first sequences the activities and then applies a time scale to meet the overall deliverable of the project, as defined in the Scope. These documents are used in conjunction to estimate the length of time each activity is to take. The scheduling tool used in this sequence is the Gantt chart which is shown below in Figure 4. Within a project, there are many technical and non-technical tasks that are equally important. The purchasing and procurement of components is a non-technical task that can be very time consuming and greatly impact the timeline of a project. Once an order is placed, some items take only days to process and receive while other items have significant lead-times and can drastically impact the timing of a project. Using the tools of activity sequencing and Gantt charts can be used at this early phase to determine the length of the project tasks such as design, analysis, experimental verification, purchasing, procurement, assembly, testing, and final assembly.

	Week						
Task	1	2	3	4	5	6	7
Define specs for redesign	■	■					
Determine component list		■					
Order components			■	■			
Design and make circuit boards					■		
Software integration					■		
Test and Troubleshoot						■	■

Figure 4: Sample Gantt Chart

The final element of the PMP Project Planning section is to list the roles and responsibilities that address each of the WBS items. With this agreed upon by all the team members, the individual contributors can start to focus and take ownership of their items with a clear understand from the Scope as to their deliverable. By including a document that clearly lists the WBS item and the team member assigned, confusion about which team member will complete various tasks is avoided.

B. Requirements Documents

At this point in the WTOC, our student design team has a clear understand of the project scope and team member responsibilities from the WBS. The Gantt chart drives the timing and sequencing of each task. With a clear vision of what is to be done to complete a successful project, the individuals are ready to begin execution of the project. Referring back to Figure 1, the second phase of the WTOC is developing the Requirements documents as shown below in Figure 5. In this section of the WTOC the student design team completes the design and analysis task associated with meeting the project deliverables. The items from the WTOC are an example set of tasks required for most engineering projects. The list is meant to be flexible such that not all projects will require all of these tasks, or the tasks required will be similar, but not exactly as listed in this WTOC. The project and faculty sponsor can work to modify this list as best suited for that particular project.

II. Requirements documents
A. Functional block diagram (hardware and software)
B. Hardware and Embedded System Tradeoff Analysis
1. Three possible solutions
2. Pugh Matrices
C. Software Design
1. Software requirements specifics
2. Software design document including flow chart
3. Justification of embedded system solution
D. Proof of Concept (Schematics)
E. Agency Approval Requirements
F. ABET Documentation
G. Risk Management Plan
H. Final Budget
I. Demonstration of Design
1. Test plan
2. Test equipment requirements

Figure 5: Requirements Documents of WTOC

The first item in this section has the students to develop a functional block diagram of their project solution, an example is shown in Figure 6. This diagram provides a graphical representation for the design and can be very helpful in explaining the solution to sponsors, team members, and those interested in the project. From this diagram, all parts of the system should be representative and the connections from system block to system block should be clear. A good functional block diagram should speak to a mid-level project description and be more informative than the high level overview, but not as detailed as an engineering drawing or schematic.

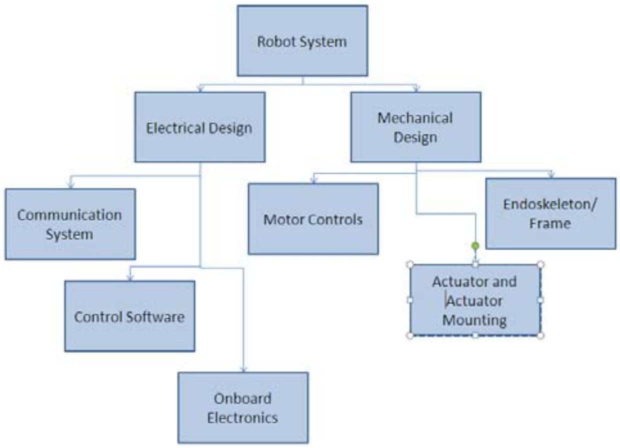

Figure 6: Functional Block Diagram

Since the focus of the course sequence is electrical engineering projects, the majority of these tasks are focused on providing the design, or the use, of an electronic embedded system to meet the project deliverables developed within the project scope. This electronic system will normally have a hardware component as well as a software component. Some project may have one and not the other, but for the WTOC both are listed for generality. In this section, the selection criterion of the embedded system is presented and the reasons the embedded system was chosen are explained.

When software is required, the student engineers are to deal with the software design as a system which includes the appropriate level of documentation is required to drive the design. With this approach the students are asked to develop a Software Requirements Specification (SRS). This document is to clearly specify the function of the software. With the SRS in place, the engineer can then design their software, and this document is called the Software Design Document (SDD). From the SDD the code is created very quickly and the team members can reference back the SDD in creating this code. With the SRS and SDD, the software task can be broken up into parts with multiple people coding in parallel all the while making sure the software meets the specification laid out in the SRS.

The remaining items of the WTOC are focused on managing constraints based on project specifics. Some projects will be approved by third party, or in house requirements. Due to this constraint, the teams document the requirements and define in their analysis and design the "how" and "why" their design will meet these constraints. These constrains may also drive tests required in the subsequently described Test Plan. As the students are completing a course, either EE400 or EE401, to meet their degree requirements, they must fulfill ABET requirements which include the documentation of how their project "meets desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability." [1] While the students are completing their design, special attention is paid to the identified risks that where identified within the Scope and an effort is made to ensure the design meets those constraints.

With the design maturing and meeting the project deliverable in the presence of constraints, the hardware schematics, SRS, SDD, and final budget of the proposed project solution is realized. With these documents created, this information is formalized and presented. It is imperative that the design team reviews their requirements from the Scope to make sure all deliverables are meet in light of the pass/fail criteria such that the proposed solution will be successful.

The student design team is asked to provide some type of design demonstration to validate their analysis. This could be a software-based simulation using a tool like Matlab or Multi-Sim, but more likely will be a partial mock up of the purposed system. This system is referred to as their Revision 0 (Rev.0) system. Using their Rev.0 system, the team is to present and complete a test plan. This test plan should represent all the constraints as defined from previous sections of the WTOC. With their Rev.0 system passing their purposed test plan, the student teams will have confidence their final design will meet all project deliverables.

C. Execution and Closing

With the Rev.0 system successfully completing the test plan, the team is ready to move to the third and final stage of WTOC, Execution and Closing. The outline of this phase is shown below in Figure 7. In this phase the team finalizes the design by fixing any problems found through the initial testing phase. At times there will be sufficient problems with the initial design that the teams will need an additional revision of the system and testing trials. The project sponsors are asked to make that decision as to when the design team is ready to move forward. When they are, the team will finalize their design and documentation. These results are flexible to the given project and the items listed in the WTOC can be modified based on recommendations from the sponsors. Normally, these items will include their design and analysis documentation, proof-of-concept simulations, hardware schematics, the software documentation (SRS, SDD, Code), testing data as defined in the test plan, list of Scope changes agreed upon by design team and sponsors, the modified Gantt Charts with actual project timing, final project budget, along with any other pertinent documentation.

III. Execution and Closing
- A. Final design
- B. Design Results
  1. Input/output data, power requirements, ect.
  2. Statement about compliance with recognized safety codes if appropriate
  3. Statement of problems encountered in design and how problems were resolved
  4. Discuss design changes
  5. Schematics
  6. Actual schedule of events
  7. Cost of project
- C. Results of testing

D. Conclusion
E. User's manual
F. Final presentation
G. Spec sheets
H. Status reports
I. CD (includes all documentation, code, schematics, presentations, etc.)

Figure 7: Execution and Closing of WTOC

If the project requires a user manual, this would have been identified within the Scope. To meet these requirements the student design team would be asked to create this manual based on the specification of the final design. There would be acceptance criteria as defined by the project sponsor as to the completion of this task. The manual would be present in any closing documentation.

The student design team is tasked to create a report to close out their course sequence requirements which contains the project information as described previously. The students are tasked to give presentations throughout the project sequence as well as a final presentation to summarize the results of the project in closing. All of these presentations should be included within the closing documentation. The design team is asked to make a CD or DVD of all project material with a section clearly presenting the project report and presentations.

V. Conclusion

The capstone design sequence in the EE program at WKU is a successful culminating sequence which prepares students for challenges they will meet in their professional careers upon graduation. Through a variety of assessment means, the EE faculty determined that these courses would be a richer and more effective experience by the incorporation of project management topics and practices into the courses. A detailed project management approached described in this paper has been incorporated into the capstone design sequence. As a result, the student projects are better managed and the students are more effective in meeting their design objectives.

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Information Technology in Logistics: Teaching Experiences, Infrastructure and Technologies

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Abstract—**Information Technology has always been a popular choice among high-school graduates when deciding on a field of study. Despite the comparatively high education levels among Latvian employees, there is still a lack of knowledge and practical skills crucial for competitiveness in a market based economy. In order to ensure relevance of the qualifications and adaptability in the fast changing environment, active learning and teaching have a special importance. Recent developments in information technology call for a serious reconsideration of the actual teaching methods and provide opportunities for developing a new educational methodology. This paper focuses on experiences of application of information technologies within the course of Logistics Information Technology for developing students' practical skills and abilities. Experience shows, that social emotional skills and abilities of nowadays students have better response on interactive collaboration, especially on active methods of teaching. Therefore, the necessity for an active teaching and learning e-environment is highlighted, and its possible realisation with application of Web 2.0 technologies is discussed within the course of Logistics Information Technology.**

Keywords—active teaching and learning, information technology, logistics information technology, web 2.0

I. INTRODUCTION

Information Technology has always been a popular choice among high-school graduates during the last decades. Admissions statistics of Latvian higher schools shows that Computer Science and Information Technology are always on top among fields selected by enrolees as their future career. However, despite a comparatively high education level among Latvian employees, there is still a lack of knowledge and practical skills critical for competitiveness in a market based economy, and namely on logistics. The current paper focuses on application of IT within the course Logistics Information Technology (LIT) for developing student practical skills and abilities. In fact, information technologies within LIT are not only the subject of teaching, but rather part of didactical tool aimed at demonstrating the power of IT in every field of application, such as logistics, education, entertainment and others. The possibility of learning information technologies/systems by applying them in studies allows students (1) to understand the basic principles of IT in Logistics (which is the aim of the course), and (2) to evaluate the variety of its applications for different solutions (which is the outcome of the course). This, according to Bloom's Taxonomy of Educational Objectives, can be explained as student growth through development of their intellectual skills and abilities.

Ten year experience of teaching LIT and researching students social emotional characteristics shows the necessity of reconstructing LIT teaching methods and learning platform in a way to support active teaching as much as it can be possible within the course. The dramatically fast growth of Information Technology, which is the main subject of the course, does not allow lecturer to stay passive without updating all teaching and didactical material monthly. Moreover, students' background in information technologies and their professional skills are always the challenge for the course lecturers. The lecturer has always to be able to give professional answers to questions which are out of studying programme and actually covers just up-to-date information technologies issues.

The objectives of the paper are formulated as follows. First the experience in teaching Logistics Information Technology is shared pointing out development milestones of the course. Then, the necessity for applying active training and teaching within the course is summarized. Finally, main specifications for learning management system within LIT are pointed out leading to a conclusion of necessity of applying Web 2.0 technology into the course. According to the objectives pointed, the rest of the paper is structured as follows. In the beginning, introduction to the subject of Logistics Information Technology is presented and the necessity of developing the course is highlighted. The syllabuses of the course, as well as some pedagogical notes are discussed.

II. INTRODUCTION TO THE COURSE LOGISTICS INFORMATION TECHNOLOGY

A. LIT milestones

The symptoms of necessity for the course Logistics Information Technology in the Master Curriculum on Information Technology were pointed out firstly during participation in the European project „INCO Copernicus AMCAI 0312 (1994 – 1997) "Application of Modern Concepts in the Automated Information Management in Harbours by Using Advanced IT – Solutions"". The project results showed a great lack of logistics specialists having efficient knowledge in information technology [1].

The course of LIT was developed for the post graduate students of the Department of Modelling and Simulation in 1998. The course curriculum became an outcome of the project LOGIS LV-PP-138.003 "Long-distance tutorial network in "Logistics Information Systems" based on WEB technologies" (2000-2002). As well, the lectures and training book "Logistics Information Systems" book was published covering the main topics of the LIT course [2].

The enhancement of the course curriculum continued within participation in the next project LOGIS MOBILE LV/B/F/PP-172.001 (2004 – 2006) "Competence Framework for Mobile On-Site Training in Logistics Information Systems". The novelty of it was the use of mobile telecommunications in learning and training in the area of LIT, combining them with m-training and e-learning methodologies [3].

In the LOGIS MOBILE project usual training methods are changed fundamentally, from e-learning to m-training, together with reducing the amount of study material. Instead of comprehensive lectures and a training book it was decided to prepare, as compact as possible, a concise training dictionary in LIT. The most frequently used terms in LIT are grouped in the dictionary. There is a control question at the end of each term explanation, which would let users to check their knowledge. Mobile phones could access this study service. Computers would no longer be necessary.

In 2005, the course materials were located on the Web at http://www.logis-edu.com. Since 2007 the description of the curriculum has been located on the ELA-LogNet website. The ELA-LogNet site is a logistics education network of universities and non-academic training organisations interested and involved in initial and further education and training in logistics to promote all types and levels of logistics learning by means of all new technologies in pan-European collaboration. In 2008, co-funded by the European Social Fund, a text book in Latvian on Logistics Information Systems was published covering basic topics of the course, as well as lab descriptions. In 2009, the course curriculum was re-viewed and some critical improvements were made. The current syllabus of the course is presented in the next section.

B. LIT syllabus

The LIT course is aimed at providing students with high level knowledge, skills and competencies in Logistics Information Technology through the integration of theory and practice. The course focuses on the application of information technologies to logistics management. It is divided into two parts: Logistics Information Technologies and Logistics Information Systems. Due to the high correlation between both of them, information technology applications in logistics management should be first explored before going deeply to the subject of Logistics Information Systems, which in turn are applications of appropriate information technologies to the realisation of logistics functions. However, the important point is to observe information technologies in the context of logistics management. Fig. 1 explains the LIT course main components.

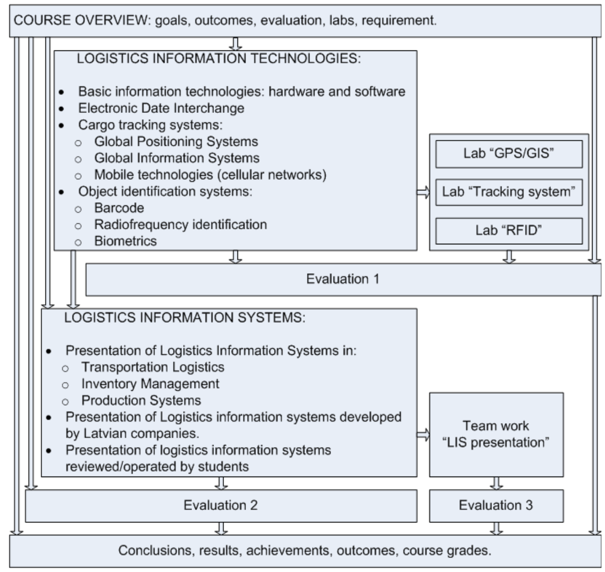

Figure 1. Main Components of LIT Courss

As shown in Fig. 1, the course is structured into several blocks. It starts with a course overview block. According to the first principle of andragogy which states that, as the learners need to know why learning is important and how learning will be conducted, the course structure, goals, outcomes and requirements must be discussed first. Moreover, a response to IT professional standards should be provided underlining the role of the LIT curriculum for getting a professional diploma of Master in Information Technology. This is normally done in interactive discussion sessions, if the number of students is not too great. Finally, the lecturer outlines the course structure, its goals and outcomes.

The second block of the LIT course covers the main topics in Logistics Information Technologies, such as Cargo Tracking Systems, Global Positioning Systems (GPS), Geographical Information Systems (GIS), Methods of Automotive Identification (Bar codes, RFID, Biometrics), Industrial Networks, Electronic Data Interchange, Mobile Technologies in Logistics etc. Actually, they all are sub-blocks within the main Logistics Information Technologies block. The sequence of the sub-block through the course is not precisely defined, and is flexible to any lecturer/students requirements. Along with this theoretical block, students should improve their practical skills performing several tasks during three labs, descriptions for which will be provided in the next section. The evaluation test finalises the block of Logistics Information Technologies and allows students to summarise and analyse it during preparation for the evaluation.

The next block of the LIT course is aimed at both exploring and introducing the variety of information systems in the context of logistics management. Several solutions are discussed in the fields of transportation logistics, inventory management, warehouse logistics, production etc. In each case the focus is on the functionality of the system for supporting related logistics functions. However, besides exploring the functionality, technical solutions are also discussed in order to underline the correlation between information technologies and information system. For example, when discussing every logistics information system, the following questions are debriefed: hardware (not only the common use like computer, fax, or whatever, but also GPS tracker, or RFID scanner), software, data transmission solutions (local network, Wi-Fi, mobile network, EDI etc.), and information technology (GPS, GIS, Biometrics, etc.). In parallel with lecturer's (and invited industrial partners' as well) presentations, students make their own presentations of different logistics information systems. This task is performed as team-work and is aimed at both enhancing students' professional competence and their group working skills. The block is finalised by evaluation tasks (see the section on evaluation for detailed explanation).

C. Labs

Although there are many different modern approaches to enhance learning by students through e-learning and m-training, the lab-based approach has gained popularity in recent years. It is recommended that labs should form an integral part of the undergraduate IT curricula. In the context of this, two lab assignments in LIT curriculum were developed and implemented in 2003, namely "The analysis of e-commerce systems" and "GPS and GIS application for object positioning monitoring". Lately, in 2007 "E-commerce" was replaced by the new one, namely "Cargo Tracking Systems Analysis", and in 2009 a new lab on "Radio Frequency Technology applications in Logistics" was added to the LIT curriculum. At the time of the preparation of this paper, the course consists of three lab assignments aimed to develop and enhance students' practical skills and competences in LIT. Table 1 provides a description of the lab exercises:

TABLE I. DESCRIPTION OF LIT LABS IN 2009

Lab	Lab description	Outcomes
"GPS and GIS systems"	Students learn the basics of GIS and GPS. They use GPS receivers to collect data (geographical coordinates) of the defined route and then analyse collected data using geographical information systems (learn how to calibrate maps, read GPS receiver data and analyse data).	Understanding the principles of GPS; Understanding GPS accuracy errors; Map calibrating skills; GPS data importing skills; GPS data analysis ability.
"Cargo Tracking Systems"	Students work with cargo tracking systems. A student team is separated into two groups. The first group makes a route outdoors while the second group follows their movements by means of the tracking system.	Enhancement of GPS principles by using mobile technologies; Tracking software operational skills.
"Radio Frequency Identifica-tion"	Students make experiments with RFID tags; write/read information; test influence of different factors (magnetic field, water, metal etc) on RFID operational capability.	Understanding RFID physics; Ability to write/read RFID tags.

D. Student Evaluation

The student evaluation process is a critical challenge for every academic course. It should be realised in a way which:

1. allows adequate evaluation of student knowledge;
2. is effective for learning and in fact is part of learning;
3. covers students personal character traits (for example, some of them perform better on tests, some benefit more in oral examinations, others do better writing essays).

Initially, the evaluation of students was conducted at the end of the course and was organised as an examination. In this, students choose a topic for discussion at random from a number of cards. After a brief preparation period, students present their topics and receive a grade. However, the shortcoming of this method is the limited number of questions students may answer in a limited time period. Due to that, since 2004 the examination processes has been supported by an on-line test which consists of more than 500 questions covering the main points in LIT. Students answered about 40-60 questions in a one hour time frame. This allowed the evaluation of a wider range of student knowledge and avoided any claims of unfair assessment. However, the main shortcoming of this is that examination at the end of the course usually leads students to postpone their studies to a few days before the exam.

To improve the evaluation by making it an assessment-for-learning, in 2009 a new evaluation system was implemented. The final grade for the course is derived from these three components: (1) a first evaluation after the "Logistics Information Technologies" block, (2) a second evaluation after the "Logistics Information Systems" block, and finally (3) a third evaluation for team-work at the presentation of the LIT system.

Each evaluation has its own weight and allows students to complete their final grade points during the semester. This can be called a portfolio assessment, in which students gather artefacts that illustrate their development over time. If a student is not satisfied with a final grade, it is always possible to improve the grade by taking a written examination which covers all course questions. The evaluation portfolio in the LIT course consists of:

- An on-line test with 60 questions which covers the block of Logistics Information Technologies (Evaluation 1 in Figure 1);
- Written essays on three questions in the context of block Logistics Information Systems (Evaluation 2 in Figure 1);
- Team-work and lecturer presentations of the Logistics Information Systems (Evaluation 3 in Figure 1).

While there are still some shortcomings in the current evaluation, the new way of assessing students provides the following benefits:

1. motivates students to study during the course;

2. minimises psychological stress during the assessment, by providing opportunity to improve the grade during next evaluations;

3. provides a variety of assessment methods way for students. This is an essential point for discussion in a pedagogical context, because there is no just one 'best' way of examining the students. Some of them being "slow-thinkers" would feel a lot of pressure due to time limitations during the test (in evaluation 1). Others might feel more comfortable going deeply into the subject (as is necessary in evaluation 2), and some like to give direct answers to precisely-defined questions;

4. supports both individual student work (and responsibility for the outcome) and team-work (where the responsibility for the evaluation is spread among all team workers).

The evaluation portfolio components may have differential weights which can be easily updated by the lecturer before the course is started.

III. PEDAGOGICAL NOTES IN LIT

There is little difference between the terms 'teaching' and 'learning' in the current paper. 'Teaching' is explained as part of educational process, where an active position (or role) is taken by a lecturer who presents (teaches) some material to students using different methods. Illustratively, a didactic lecture is a trivial method of teaching. In contrast 'learning' can be explained as part of an educational process, where students actively construct their own knowledge by absorbing, understanding and analysing information provided by the lecturer. We can assume that the student's role in teaching is more passive compared with the lecturer's, however learning is driven more by students (with some support and coordination from the lecturer's side).

In LIT, the main focus now is on supporting students in active learning and, if possible, in student-centered learning. By active learning we understand "instructional activities involving students doing things and thinking about what they are doing". Active learning is the idea that different people learn in different ways. Understanding how learning can be realised, which is the better method of learning for each student and to provide different learning styles for students is one of the pedagogical objectives of LIT. Teaching aids include text books, slide-show presentations and different video materials etc., see Fig. 2.

Every teaching process consists of three components: students, teacher, and an environment. In teaching, the role of the lecturer is dominant and usually performed by a trainer (instructor, lecturer). In learning, the main components are students and the learning environment. The lecturer's function here is to support students with a variety of methods, tools and environments. In this section, we consider the LIT course audience and discuss some teaching methods and tools specific for students doing studies in technical fields.

Despite plenty of traditional didactical teaching aids, the actual focus now is on improving the quality of educational process applying different IT solutions, especially at the Faculty of Computer Science and Information Technology of Riga Technical University. Academic personnel point out the great importance of using modern technologies in teaching. Illustratively [4, 5, 6, 7] describe the application of IT solutions in developing effective e-learning and evaluation methods.

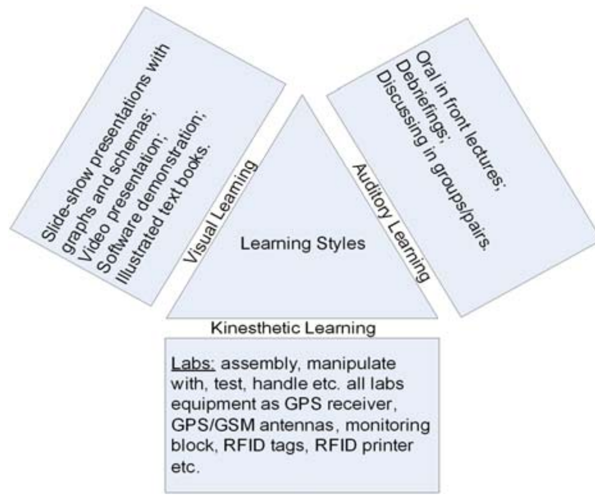

Figure 2. Supporting learning styles in LIT

A. *Course audience*

The understanding of the students taking the course is a quite essential point in any educational process. Prior experience of the learner undoubtedly impacts on the process of learning, partly because students get their experience not only at university. The LIT course is developed for postgraduate students doing full-time Masters Studies in the field of Information Technology, so prior knowledge in information technologies and computer science is preferable. This cannot be regarded as a challenge because (1) professional competence in information technologies is presumed, when one is a student in the Faculty of Computer Science and Information Technology, and (2) the course in Logistics Information Technology is a logical enhancement of the course of Logistics Information Systems Basics which is part of the Bachelor's Curriculum.

The LIT course consists basically of postgraduate students whose average age is 22-24. Almost 90% of LIT students are employed either in private companies or in government organisations, which makes them to be extremely high demanded for qualitative learning and teaching processes. Most of the students work in the IT field, which gives them deeper professional skills. For that reason, lecturers need to be able to adjust course material to suit students experience and prior knowledge. Some features of LIT students noticed during the teaching experience are:

- students ask for concise information;
- need more practical illustration;

- share their own experience about subject;
- prefer debriefing sessions to lessons;
- prefer labs to lessons.

B. Teaching methods

According to our experience, a lecturer must organise the course providing a balanced learning experience using different learning methods, i.e., lectures, labs, discussions etc., see Fig. 3. To illustrate, during typical classroom lectures, conceptual and theoretical information (intuitive learning) should be supplemented with concrete, practical information (sensory style) expressed through lecturers comments and explanations. Pictures and diagrams of slides presented to visual learners must also be explained orally for verbal learners who seek explanations having words. Active learners prefer to do physical experiments and to learn by expressing themselves working in groups. They appreciate conducting lab exercises which can promote the students cognitive activities. For reflective learners, however, we provide tasks, such as evaluating different options (i.e., different cargo tracking options in the second lab exercise) and making analysis (of the data acquired in Lab 1).

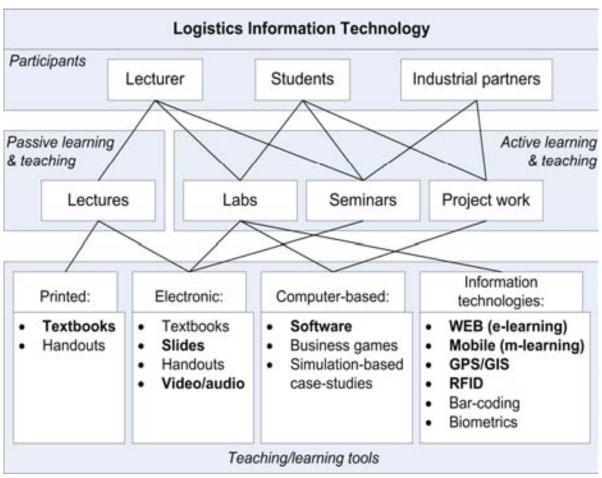

Figure 3. Teaching components in LIT

LIT employs lectures as the most used teaching method. This can be called a passive teaching method, where the lecturer has a major role. Lectures are mostly used in the Logistics and Information Technologies block; however it still has some active learning elements such as debriefing, discussions and 5-minute activities done in pairs. The Logistics Information Technologies block is organised using workshops, seminars and team-projects. Here, both lecturers and students have active roles, so this block can be characterised as an active learning support block.

Laboratory exercises are traditional method of active learning. Labs can be used to facilitate the exploration and illumination of difficult concepts. Most importantly, labs can enhance the cognitive learning process, which is often referred to as the integration of theory with practice.

In fact, information technologies within LIT are not only the subject of teaching, but rather part of didactical tool aimed at demonstrating the power of IT in every field of application, such as logistics, education, entertainment and others. The opportunity to learn information technologies/systems by applying them in studies allows students (1) to understand the basic principles of IT in Logistics (which is the aim of the course), and (2) to evaluate the variety of its applications for different solutions (which is the outcome of the course). This, according to Bloom's Taxonomy of Educational Objectives, can be explained as student growth through development of their intellectual skills and abilities.

IV. Teaching / Learning Environment in LIT

The application of information technologies for the purpose of education in LIT started almost directly after the course had finished (see table 2.)

TABLE II. IT IN LIT LEARNING

Year	IT Solutions	Pedagogical goals
Since 2004	On-line test	Student final evaluation, using on-line test
Since 2006	Mobile training	Student self-evaluation of main logistics information systems terminology, precise vocabulary
In 2007	Moodle	publishing announcements for students, providing lecture materials & handouts, giving assignments for practical work; communications
Since 2008	ORTUS education e-environment	publishing announcements for students, providing lectures materials and handouts, giving assignments for practical work; communications; evaluation desktop; course evaluation by students

Application of modern information technologies for teaching/learning purposes in LIT started firstly with using on-line test as evaluation. Lately, m-learning elements were included for student self-evaluation in main terms of LIT.

Application of Information Technology as an environment started in 2005, when all course materials were located at Learning Management System Moodle. Application of Moodle was aimed to facilitate educational process and make it more efficient and interactive, as well as for distance learning purposes. Moodle provided different means for educator and students that allow performing day-to-day operations in a much more efficient way, for instance publishing announcements for students, providing lectures materials and handouts, giving assignments for practical work and labs. In this case students were able to access all necessary materials and information from anywhere at any time when Internet is available. Also it is possible for students to stay in a permanent contact with their lecturers, which is important when personal communication is impossible (for instance, in the case of distance learning). The next step in enhancing a learning environment took place in 2008 in overall way for all RTU students. ORTUS is an environment created on the basis of LMS Moodle as a single electronic educational environment of RTU. It provides high-quality support for an educational process. However, ORTUS does not allow the use of objects, to be placed inside the educational modules repeatedly; or the use of materials, created by lecturers and students, to remain in a study programme, so that in the course of time a student loses access to them. Also, using ORTUS it is not possible to organise a comfortable educational space for active co-operation between students working on team solutions to educational tasks.

Despite plenty of benefits being provided by above mentioned solutions (mostly related to the possibility of using them outside of class), there are still some shortcomings. The following can be mentioned as main issues:

- There is no single e- environment that co-ordinates both learning methods and tools in one single platform. The on-line testing system is physically located at another website, the ORTUS structure is formed by RTU IT department and, in fact, provides only limited functionality for active learning.
- None of the mentioned solutions provides an environment for active learning. Actually, all of them serve as storage for keeping such teaching material, as slides, video/audio, handouts etc. The only active processes are forums and on-line tests.

All the above mentioned leads to the final conclusion concerning the necessity of re-designing the e-learning environment in order to satisfy the following requirements for active learning:

1. to implement active learning tools and methods;
2. to maintain learning activities like communication, discussions, team-working;
3. to support both collaborative and co-operative learning;
4. to support the lecturer's role as an active participant and co-ordinator, rather than as promoter;
5. to allow students to create valuable cooperative, collaborative and individual products, (for example, project works), which can later be used by students in their professional carriers.

When analysing applications of IT for teaching purposes, it is possible to select a number of influencing factors. In our opinion, the most important of them are the increased amount of information related to the permanent development of technologies and entrepreneurial activity, and the mass introduction in teaching the technologies on the basis of the Internet, including Web 2.0 technologies. The first factor causes changes in knowledge of the specialisation, and determines the main requirements of the environment for teaching, the rapid transmission of knowledge and abilities of the students and researchers from different geographical regions. The second factor allows an increase in the creative potential of students, provides joint creation and use of information resources and collaboration and expansion of functional possibilities for teaching. Contemporary students want teaching in the form of an active dialogue and to be in a position to have an impact on the course of events, that is, they want to be competent participants in a teaching process, the authors and reviewers, as the student-centered model foresees it.

Following the definition of Tim O'Reilly [8], Web 2.0 is the technology for designing systems which, through network co-operation continue to develop as more people use them. The main feature of Web 2.0 is to attract the users to create knowledge by introducing home page content and to use the principle of frequent verification. In the base variant of Web 2.0, every person could easily create and spread content in the World Wide Web. It could include records in weblogs, pass video information through YouTube, place pictures in Flickr, help in the creation of content in wiki, as it is actualised in Wikipedia, and also create social networks of the Myspace type. Thus, contrary to Web 1.0, which makes service to a vertical «Teacher-Student» relationship, the Web 2.0 technology is characterised by development of horizontal connections and works on the basis of social ties and relations.

The high popularity of Web 2.0 in social environment asked to its serious analysis as a tool which can be applied as teaching and learning platform. There are plenty of researches on Web 2.0 benefits as a pedagogical tool. Illustratively, [9] shows a significant reason for educators to turn to Web 2.0 as it seems fit with certain experiences emphasized in contemporary theories of learning and modern thinking. The research presents a response of Web 2.0 within the psychology of learning, namely four influential but overlapping frameworks as behaviourism, constructivism, cognitivism, and the socio-cultural perspective. It is concluded that Web 2.0 technology makes possible individual efforts of knowledge construction; it provides tools for more probing self-reflection; and, most significantly, Web 2.0 stimulates the experience of learning as interpersonal and communal in nature.

The key components of Web 2.0 are easy-to-use instruments and general or social relationship systems having the expected results. One of the most interesting results of the use of Web 2.0 is the phenomenon which is often named 'Collective Intelligence', describing the situation when the potential influence of information between the users of World Wide Web grows very quickly. It is very important, that this index increases with the increase in the number of persons actively contacting each other through World Wide Web that provides people with possibility of joint search, creation and the exchange of information. The research of McKinsey [9], Forrester [10] and other authors in the area of the application of Web 2.0 technologies, shows recently growing active interest in the phenomenon of Collective Intelligence. It has also resulted in an increase in the amount of investment in Web 2.0 technology. Researchers point out that for effective creation of new decisions and knowledge it is necessary to aggregate the possibilities for users of the input of information, methods of joint activity, and also modern technologies of collection and processing of information (wiki, weblogs, widgets, mashups etc.).

As a result of research on improving LIT teaching, the main conceptual requirements were formalised for the developed environment of e-learning with the use of modern approaches and IT technologies. It is necessary to provide the e-environment having the following basic functionality:

- permanent development of educational materials, with the possibility of their modernisation by authors and teachers and by students. Traditional electronic courses serve only as base information sources;
- generalisation of existing knowledge and the creation of new knowledge – students create materials themselves and communicate with other students through technologies, enabling the distributed creation of materials and division of responsibility in the process of forming and the use of resources;
- use of large sections of the aggregated information sources in the process of teaching, which includes in itself all possible formats of files and methods of their transmission;
- the study of materials takes place at any time and at any place: all information sources can be used not only by computers but also by mobile telephones, MP3 players etc.

The development of these new possibilities for e-learning environment will be based upon the instruments of Web 2.0 technology, such, as weblogs, wiki, podcasts etc.

Articles written on weblog technology form an analogy of the classical concept of scientific theses and create electronic home pages of a persons or organisations on which the collection of information is made on a concrete topic or topics, including regular updates of this information. Information can be written down in a weblog by a proprietor. It can be re-written from other weblogs. The readers of a weblog can also supply information, make comments on themes and discuss different questions. Automatic creation of templates is thus possible for theses published in a weblog, using information from the pages of wiki and personal notes associated with them. A weblog can be integrated with other weblogs. The results of continued experiments, current results of work and newly synthesised ideas, can be written down in a weblog.

It is possible to select the different forms of weblogs for the teaching of LIT, firstly as a means of communication between students concerning organisation of the course, the performance of tests and home tasks, and the support of different student initiatives, secondly, for additional discussion of course themes, conducted by a teacher and the encouragement of students to make independent analyses of the information received. In such weblogs, teachers will formulate questions and tasks for students, and also give references on additional materials and resources for the topic. Thirdly, for the students, using weblog on a research theme can become the method for bringing in comates and teachers to make comments, and to criticise and correct the method of preparation.

The addition of the use of weblogs for teaching LIT can be a forum – a traditional asynchronous mechanism of communication. A forum can be related to any theme, document, person, or weblog. A forum provides bilateral connections and enables both comments on the theme and the comments of other users.

For the personal base of knowledge modern technology of wiki is appropriate. Wiki is a home page which, in the asynchronous mode, is filled with information from a group of people and can be used as a mean of accumulating knowledge on a certain topic in the process of collective work. The basis of wiki is represented by a graph, where knots are noted by keywords (terms) and vocabulary entries associated with them. Personal wiki can be integrated with other wiki's, for example in Wikipedia and other dictionaries and encyclopaedias.

In teaching LIT, the use of wiki is assumed for the joint performance of laboratory exercises and course projects, and also for group discussions having a possibility of giving references on additional materials. Upon completion of every block of the course themes, students apply the acquired knowledge in practice and by wiki resources to collect new ideas, descriptions of interesting decisions etc. relating to this block of themes. In the future, they can be taken into account in a new modification of the course or to create independent educational content themselves.

To provide the course with a great number of aggregated information sources, it is possible to use podcasts. It will be used in the teaching of LIT for distribution among students by audio and videotape recordings including courses or comments on a study programme. Creation of podcasts is also planned by students themselves, summarising the results of their research in LIT course.

Conclusion

Recent developments in information technologies and telecommunications facilitate the development of new training and educational methods and tools, as described above. This provides possibilities for organising educational processes not only in the traditional way, but also by means of active learning, combining IT technologies with modern pedagogical approaches. This is of special importance for LIT teaching, where IT is the main subject of the course.

Current improving of LIT teaching relates to redeveloping course context, structure (using module-based structure), and appropriate student evaluation method. Special attention is paid to developing laboratories with modern IT equipment like GPS navigators, tracking software and Radio Frequency identification technology hardware and software. The interest among students grows up dramatically with inventing labs, moreover, they became more active not only in labs, but in lectures as well. This helped to make usual lectures to be more interactive and student-oriented with debriefing sessions at the end of every lesson. However, making those essential steps toward active learning, the importance and necessity of teaching platform became obvious. Four years experience of Moodle as learning management system showed both its benefits and shortcomings. The analysis of shortcomings leads to the conclusion of necessity researching Web 2.0 in the context of LIT.

By using Web 2.0-based LIT e-learning environment, both lecturers and students will be able to create individual centres of teaching and researches on the different themes of LIT. Moreover, the designed e-environment will provide opportunities to form student personal portfolio achievements in studies and research, by submitting them in an electronic form for discussion and debriefing with co- students and lecturers.

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Session 10C Area 2: Virtual Worlds for Academic, Organizational, Life-long Learning and training - Virtual media and tools

Fingerprint Identification in LMS and its Empirical Analysis of Engineer Students' Views

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Lab2go - A Repository to Locate Educational Online Laboratories

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Fingerprint Identification in LMS and its Empirical Analysis of Engineer Students' Views

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Abstract— **This paper describes a fingerprint identification system (FIS) developed to be integrated in learning management system (LMS). Hence, a middleware is necessary to connect any LMS with our own FIS, which will provide us a scalable, robust, easy integration in any LMS. This project aims to solve the problems of identity authentication of users in remote or virtual environments whose use has spread both in distance education and traditional universities. It seeks its integration into traditional and remote environments, and in the remote environment in exams as well as virtual labs. The project aims to cover all the weaknesses that traditionally have the password or user name. The implementation starts from the own fingerprint identification system developed to its final integration in the LMS.**

Keywords-evaluation; fingerprint identification system; learning management system; middleware; virtual labs)

I. Introduction

Nowadays, there are many precise solutions for the security in physical access and even in processes online. Into the higher education is becoming a need using new security systems. Student cards with just bar code are not enough to assure the identity. In the same way, new virtual communities manage different courses, contents and tools such as: forum, chat, calendar, etc. but what refers to identification still uses user name and password to let enter to the system. Hence, it can see the necessity of developing new application that complement and intensify the learning management systems.

In higher education there are several systems and utilities that provide robustness for both teachers and students. One example is smart cards that give access to both physical buildings and specific applications of a college. However such systems do not guarantee the identity of the person in the building, in the lab or using resources of a subject. So, we need a solution for the identity of the people that access to physical building or Web applications.

The starting point of the research is to develop a biometric system [1] which has the requirements that are demanded today in higher education. The initial challenge is to deal with a branching structure, which is our university case. As a distance Education University has different centers throughout the country and even beyond our borders. This branching structure is completely transparent to the student. The student attends at his nearest center for tutoring or exams. The documentation or logistics behind a subject are hidden.

Our university has made great changes, automating the entire process, leading to what we call "virtual package". A barcode reader identifies students who access an examination room. After checking if the student is allowed to do an exam, it prints in real time a customized exam for that student, indicating the place in the classroom where the student must sit.

The new assessment model aims to use the resources of educational communities and add a new identification module. As advantages are:

- Use of resources and applications that offer the learning management systems
- Structure applicable to any LMS
- Elimination of the process of sorting and delivery of exams
- Biometrics [2] could resolve the problem of identification

Therefore this new model instead of printing the test, the test will be done by computers in the examination room. The prints just only will indicate on a label where a student must sit. Every post will have a computer along with a USB biometric reader which will identify the student and then will show his test, Fig. 1.

II. New Evaluation Approach in Local Environment

A. Biometric Technology

The new assessment model aims mainly to verify the identity of all students in both local and remote access. The choice of technology should be based on something that characterizes each individual from the rest; therefore biometrics can provide a reliable answer to our problem.

However, a 100% secure system [3] is impossible. While biometrics can minimize the risks involved in an examination, these cannot disappear altogether. Graphically the reliability [4] of a biometrics system could watch in what is called The

Biometric Solution Matrix [5] that is based on five key points: urgency, effectiveness, exclusivity, receptivity and reach. A study of biometrics in our application and our specifications required obtained two matrices: one for local environments and another for the remote, Fig. 2.

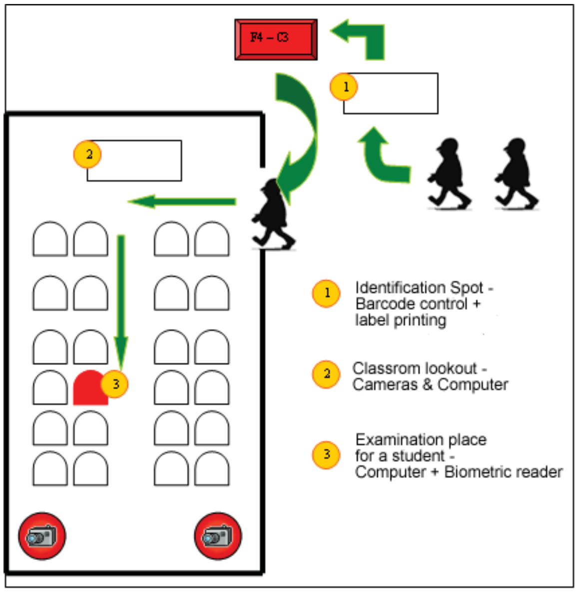

Figure 1. Schematic of the new local examination environment

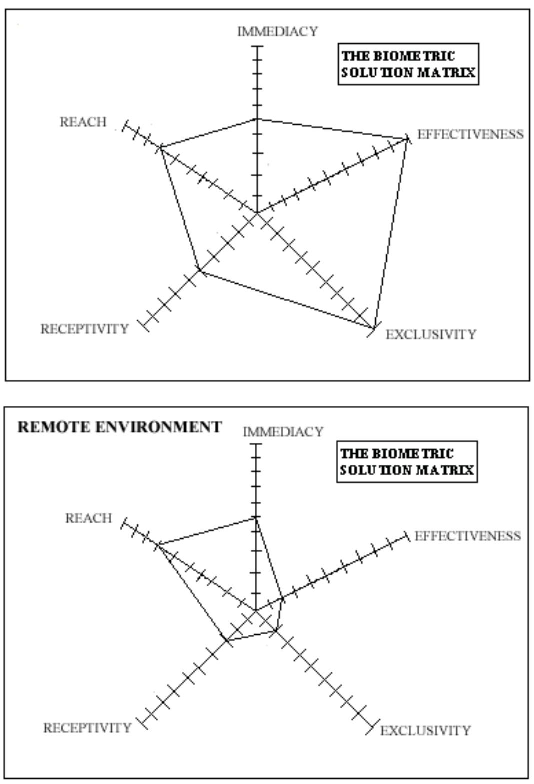

Figure 2. The Biometric Solution Matrix: Local and Remote Environment

As shown both matrices have the same levels of immediacy and reach. The immediacy show us how important are the data and whether development is needed immediately or not. In local enclosure, there is already a manual version to verify identities by ID card and in remote enclosures as they are not yet developed, hence the immediacy should have a moderate value either because there is a workaround or because data are not so important for endanger human life. The reach defines the amount of people where the biometric solution must be implemented. An application of verification for a small group would not make sense in relation use-cost, biometric systems take place in medium-high groups of students. Our university is of this kind, it handles a large volume of students every year.

The effectiveness, exclusivity and receptivity take different values in both environments. The effectiveness show us how well the system solves a problem of authentication, in local enclosure through the use of biometrics can solve perfectly the problem of identification. In remote enclosure, it is true that biometrics will give some support to the implementation, but these uncontrolled environments will have many problems to be covered.

The exclusivity present to biometrics as the only solution for an application with the need to verify identities. In local environment to our current design, the biometrics technology is presented as the best applicable technology and unique to these enclosures. In the remote environment, having a not very high effectiveness and needing other devices to control the enclosure, it is presented as a not exclusive solution needing some other methods for identification to take place at the same time.

The receptivity of students using biometrics has a moderate value in local environment, as it presents a new control that could have malfunction or give an excessive feeling of data collection. In the remote environment, the situation even worse since the implementation of biometrics must be done in a room that usually use students; the perception of intrusive technology becomes more noticeable.

Following this study we see that biometrics is a solution that fits better into the local environment, since it gets a better solution improving the current model. But in the remote environment it is insufficient and requires additional technology. Regardless of this matrix widely used to define solutions, our two environment demand greater emphasis on feasibility and costs relationship.

B. *Phases in the implementation*

The access to a class in the LMS with open permissions is done by a user name and password, which are data that can be easily acquired by others. Which puts into discussion the resources and content that must be shared with this ambiguous security.

The new service stems from the challenge of ensuring that identification. In other words ensure that the person is really the person access to such rights. This is done for a double identification using the username and password along with a new biometric application that interacts with the LMS and contents such as web exams, virtual labs, and so on.

As shown in the Fig. 3, an LMS provides the following services basically for the identification:

- Login (user/password)
- Access to Management Groups and Profiles, which gives a specific role
- Access to the resources for that role

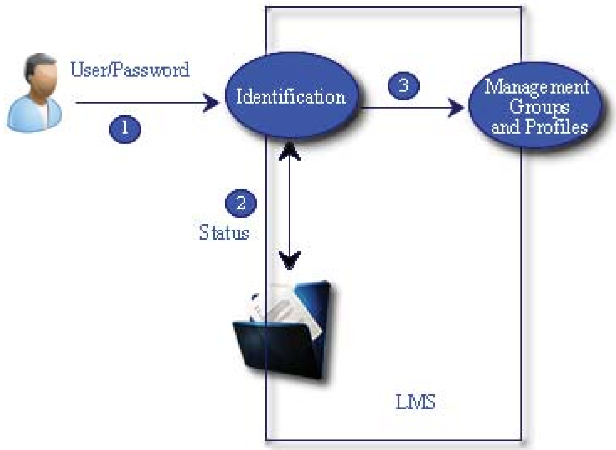

Figure 3. Basic Identification in the LMS

The new model, Fig. 4, involves adding resources that do not exist in the learning management systems. Our project should design a module applicable to any LMS, such as dotLRN, Moodle, Sakai, etc.

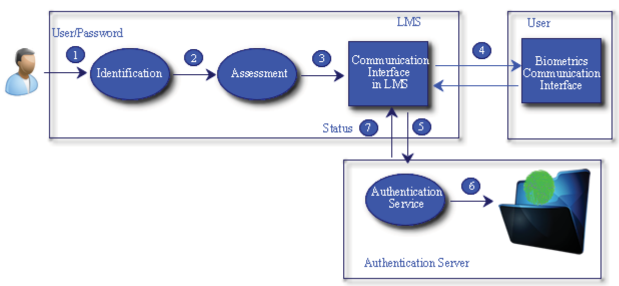

Figure 4. Block diagram of the new security model

The learning management system offers range of services among which is the option to do tests. When a student accesses to the assessment package in LMS it will start the communication between the LMS and the biometric device on the user.

The communications interface in LMS will request the capture of a biometric sample. Then, the biometric interface will send a captured sample. The next step will be to communication between the LMS interface and the authentication server.

The captured sample will be verified in the database of the Authentication server. This database will contain all the samples of students with personal data, so that the biometric matching [6] will be 1:1 from a password.

The methodology of the double identification will be:

1) The user is identified in the LMS by user name and password, which is the basic and general identification of any LMS.

2) Access to the Assessment portlet

3) As a result, it starts the communication between the LMS interface and Biometrics interface.

4) The biometric communication interface will capture the fingerprint's user and return it to the LMS interface.

5) The communication interface of the LMS provides the fingerprint captured to the authentication server.

6) In the authentication server the new sample is compared with the fingerprint database.

7) It returns the approval (status) to continue the evaluation process.

Transparent manner could envisage a repeat steps 4 to 7 during the test. This would ensure that the user does not change during the test. This check can load the system and would only be done if the examination is conducted on-line remotely, that is not performed in specialized classrooms of the UNED.

III. Design of the Fingerprint Identification System (FIS)

The fingerprint identification was the first identification system that was developed, is widely introduced in the market and consequently there is great availability and variety of devices and prices. For the implementation of an automatic fingerprint recognition system in learning managements systems, it was developed a priori in a standalone environment in order to move into LMS after some test.

This system involves an image processing, study and extraction of useful information from the fingerprints. Therefore it requires a previous phases before the extraction of information, these will be a pre-processing phase and an enhancement of the image phase. The total phases generated are as follows [7]:

- Image acquisition: Firstly, it used a database of fingerprints of free distribution accessible from the website of "Fingerprint Verification Competition, FVC". Therefore we used the database FVC2002. In this database for each user was taken 8 different samples, which was enough to test false acceptance and false rejection.
- Enhancement the image. The possible noise introduced in the capture can cause distortions in the information in the fingerprint. It is therefore important to undertake a phase of enhancement [8] of the image.
- Minutiae extraction and post-processing. This is the study of discontinuities in the fingerprint, such discontinuities are called minutiae. In this phase these points are extracted and are verified that they are not spurious points.
- Comparison of data. In the last phase of the identification system compares the new captured sample with the stored samples in a database.

The block diagram of the automatic fingerprint identification system is shown in Fig. 5.

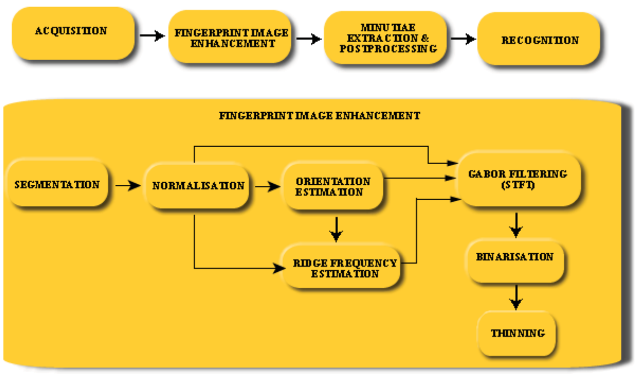

Figure 5. Block diagram of the fingerprint identification system

A. Enhancement of the Image

Some basic concepts that will be used are: ridges, valleys and minutiae. The ridges are simply the present lines in the fingerprint, so the valleys are the groove between adjacent two lines or ridges. The useful information will be the discontinuities in the pattern of ridges in a fingerprint, which are called minutiae.

Within the minutiae are different but the most general classification is to discriminate between ridge endings and bifurcations. The endings, as its name suggests the line simple simply ends and bifurcations will be a line divided into two. The minutiae points are the targets for the next phase, but the elimination of false information will do in this phase.

The enhancement phase includes various blocks, there are: segmentation, normalization, orientation and frequency of the ridges, filtering using Gabor filters, conversion to binary image and thinning. Following, it explains each block to obtain an overview of the achievements in this phase.

1) Segmentation. It selects the image area where there is useful information, also called area of interest. The result is an image with only the foregrpund of the fingerprint. It uses a variance method [9].

2) Standardization. It adjusts the intensity values in grayscale in a certain range, mean and variance desired. This does not change the structure of the image. This phase facilitate the implementation of the successive stages in the identification process

3) Orientation of the ridges. This phase is necessary because of the type of filtering is done in the following stages. Gabor filters or also known as STFT (Short-Time Fourier Transform) are selective in frequency and orientation. For the calculation of the orientation, the image is divided into blocks and each block is calculated gradients using the Sobel operators for the direction x and y. Then we calculate the local orientation of a block centered on pixel (i,j), $\theta(i,j)$.

4) Local frequency ridges. The calculation of frequency follows the same methodology as in previous stages. It divides the image into blocks projecting all pixel values in the direction orthogonal to the orientation of the ridges, which has been calculated in previous step. Such projection has almost sinusoidal shape, which minimum points correspond to the crest of the fingerprint. Thus we can calculate the distance between the first and last peak obtaining the frequency of a block.

5) Gabor filters. Gabor filters (Fig. 6) [10-11] consist of a sinusoidal waveform to a particular frequency and orientation modulated by a Gaussian envelope (1-2). As it is selective in frequency and orientation, works effectively on the ridges without affecting its structure while reducing the noise level.

$$G(x, y; \theta, f) = \exp\left\{-\frac{1}{2}\left[\frac{x_\theta^2}{\sigma_x^2} + \frac{y_\theta^2}{\sigma_y^2}\right]\right\}\cos(2\pi f x_\theta) \quad (1)$$

$$x_\theta = x\cos\theta + y\sin\theta,\ \ y_\theta = -x\sin\theta + y\cos\theta, \quad (2)$$

Where: θ is the orientation of the Gabor filters; f is the frequency of the cosine; σ_x^2 and σ_y^2 are the standard deviation of the Gaussian envelope along the x and y axis respectively; x_θ and y_θ define the axes of the filter x and y.

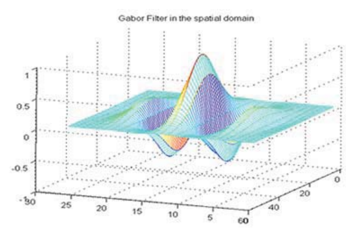

Figure 6. Gabor Filter in the spatial domain

The enhanced image is obtained from the convolution of the Gabor filter and the normalized input image. Applying this filter results an image with noise reduction, smoothing and reconstruction of the ridges.

6) Conversion to binary image. Because of most algorithms for extraction of minutiae operate with binary images, it requires the conversion of binary from grayscale. This process provides a greater contrast between ridges and valleys, where the pixels 1 are ridges.

7) Thinning of the image. In this last phase, which will be the input of the successive blocks in the fingerprint identification process, consists of thinning the width of the lines. Iteratively [12], the width of the lines will be reduced lines until one pixel width lines. As a result we have the skeleton of the input image without affecting the structure of it.

B. Minutiae and post-processing

In order to extract the minutiae point it uses the Crossing Number (*CN*) [13-14] algorithm. Such algorithm consists of scanning the values of neighboring pixels to a particular pixel P. It takes a window of 3×3 and calculates the sum of the differences of a pixel value minus the value of next pixel counterclockwise. As a result of this algorithm yields a value of *CN* which corresponds to a pixel type (Table I).

TABLE I. CLASSIFICATION OF PIXELS ACCORDING TO THE VALUE OBTAINED CN

CN	Property
0	Isolated point
1	Ending ridge
2	Continues point
3	Bifurcation
4	A crossing point

Only the ending and bifurcation ridge will be interesting to discriminate fingerprint. So the pixels with values of *CN* 1 or 3 will be stored in a database. For each minutia will be important to keep: the coordinates (*x, y*) point, local orientation and its distance to the next distance to the next minutia. Such information will be required in the matching phase.

After using this algorithm it gets some false minutiae points, which are not real information of the user, Fig. 7. This false information can be introduced by noise on the image that has not been eliminated at earlier stages and by the thinning process that could generate some random points. Then a post-processing stage is implemented, where the extracted information is analyzed. In our project was carried out following the algorithm of Tico & Kuosmanen [15], which has a common initialization phase for both the analysis of bifurcations and endings, then two alternatives: for false bifurcations or false endings.

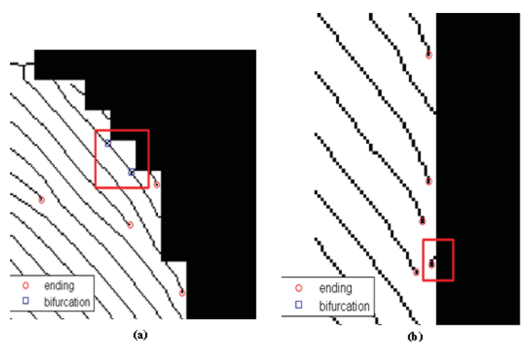

Figure 7. Results of the extraction of minutiae points: (a) Detail of the false bifurcations extracted; (b) Detail of false ending extracted.

C. *Fingerprint matching*

In this last phase of the identification algorithm is comparing an input fingerprint against the database. As we said, in the database there is local information which was extracted in the previous phases. Comparing local information [16] we will observe the relationships between points will not change. So any shift or rotation will be proportional in the both images.

Graphically all the phases of the design of our FIS can be appreciated in Fig. 8.

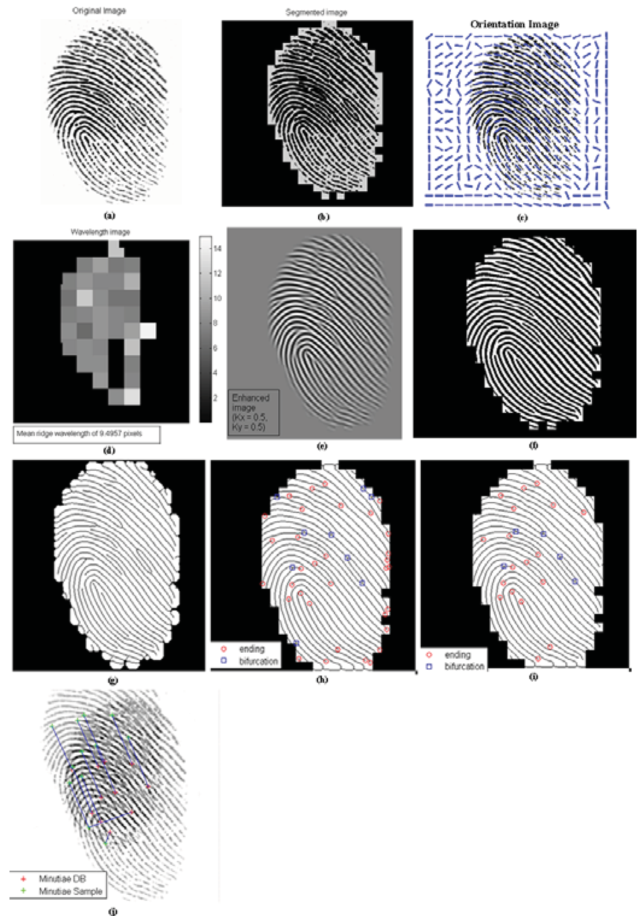

Figure 8. Fingerprint Identification System. Results: (a) Original image; (b) Segmented image; (c) Orientation image; (d) Wavelength image; (e) Enhanced image; (f) Binary image; (g) Thinning image; (h) Minutiae extraction; (i) Post processing image; (i) Matching.

IV. FIS IN ALF

The UNED uses an educational community, called aLF, to develop different contents of their courses, offers a range of services that allow a living relationship between students and teachers. It's a friendly environment. It is also an intuitive environment that requires no prior training course at the user level. That means UNED uses dotLRN as the LMS, which is an application of OpenACS, and in which aLF is based on.

OpenACS, Open Architecture Community System, is a free Toolkit, open source, which provides a fast Web application development with GPL. OpenACS architecture is based on a Web server AOLserver and as database Oracle and PostgreSQL. OpenACS provides a large set of applications that can be used to develop Web sites and is particularly useful for those who are collaborative. Some of the most important applications are dotLRN, dotFolio, Workflow, CMS, Blogging, e-commerce, forums.

It has a great set of APIs and services to rapidly develop new applications. Its data model follows the philosophy of object-oriented with standard SQL and methods with PL/SQL and support different databases (PostgreSQL and Oracle).

OpenACS is developed by TCL code and is widely used in a number of universities, institutions, companies and freelance developers.

DotLRN is a fully featured LMS-type software, open source and has a sophisticated portal system that integrates tools for managing courses, content and collaboration tools. As we said dotLRN is a system that is based on OpenACS. OpenACS is the Web Framework and dotLRN is its e-learning system and management of communities. It is scalable, robust, extensible, and with the SCORM standard. OpenACS data model implements an object-oriented that developers can modify. Users or system administrators have a Web interface that allows them to create departments and schools within which the courses are distributed.

Figure 9 shows the home screen of a course "*Pruebas del CSI"* in aLF. This is the screen to find any student in a subject.

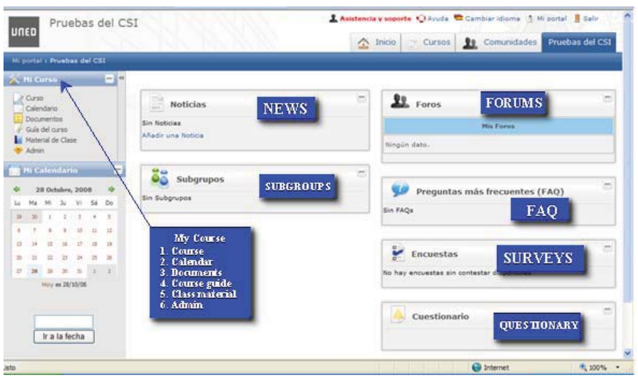

Figure 9. Start Menu for a Course in aLF

As shown on page layout is three columns with the first column narrower. In this column we present the tools, clicking on *"Material de Clase"* (Class material) one can find different exercises to be performed or documentation, subsumed under *"Tareas, Proyectos and Exámenes"* (Tasks, Projects and Exams). In this example there is an exam, called *"Prueba 1",* see Fig. 10. At this point, the LMS Communication Interface requests the capture of the fingerprint to provide access to screen or Web site of the exam.

The creation of a test by the teacher of that subject is simple; it can create a multiple-choice test or submit a URL to another page.

V. STUDY: REAL CASE IN LABS EXAMS

Evaluation is a necessary process in any training activity. If no assessment, the potential for improvement of the learning processes are not significant. The assessment helps to know the strengths and weaknesses of the training activities developed. It allows us to implement mechanisms of correction.

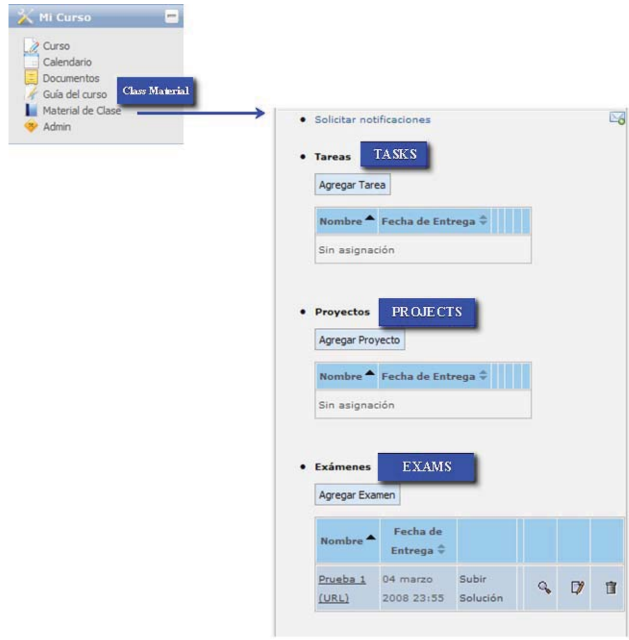

Figure 10. Class Material Options: Tasks, Projects and Exams in ALF

Three moments must be evaluated in this project:

- The design, content and strategies
- The development of the system during tests or access to virtual or remote laboratories
- The results once exams or practices in labs are over

Then, we seek a pedagogical evaluation covering the educational aspects of introducing our FIS into the LMS, including its planning, development and results.

It should be noted that levels of reaction generates the new model. Referring to the assessment that students make the quality of the new model, based on their impressions. This is an assessment of the degree of user satisfaction. Notwithstanding the evaluation results will also be important, i.e. the consequences of the new model at the level of quality for students.

So, on one side is to assess the application itself, technological, and on the other side the educational impact on student learning [17]. Table II can be seen these two lines of assessment based on the three occasions, already cited, where one must evaluate the project.

Once the module Fingerprint Identification System is created, the next step is to test its real utility in higher education. The student profile in these tests will be engineering careers. This is an advantage at the technical level, as the acceptability of introducing new technologies and ease of use is high. Users are familiar to new emerging technologies, and the use of different devices is common in their day to day. This causes the learning of another new application is fast and reduces the associated training failures.

TABLE II. EVALUATION MODEL

DESIGN	
Technological	**Pedagogical**
-Accessibility -Usability -Technical functionality of the module	-Organization (student orientation) -Objectives -Contents -Training strategies -Learning activities -Resources -Evaluation
DEVELOPMENT	
-Information / Introduction -Resolution of technical problems -Synchronous communication -Asynchronous communication	-Tutoring -Task-Management -Evaluation / feedback -Combination local / Online
FINAL	
-Acquisition of new knowledge and skills -Usefulness	

Our university has both profiles of students, sciences and arts. But the FIS module tests are intended for use in the department of Electrical, Electronics and Control engineering for industrial engineering students. At first this module is designed to apply in the subject *"Digital Electronic"* for local environments in real labs. This subject handle around of 80 students and the tests are conducted over 5 days, which means an average of 16 students per day.

After the tests of this new module to see its advantages over a traditional model is important to get values of the false acceptance rate (FAR) and the false rejection rate (FRR) as well as the measured of acceptability of users. That is the perception that they were inspired by this new module.

A questionnaire [18-19] example of parameters to be measured and which depend on the response and opinion of the students are shown in the Table III.

TABLE III. SURVEY ON THE EFFECTIVENESS OF FIS IN THE LMS

Item	1	2	3	4	5
1. Use only passwords and user name					
2. Use of biometrics in college					
3. Fingerprint is a technique intrusive					
4. Suitability of biometrics in college					
5. Improvements in the conduct of examinations Web from the traditional					
6. Integration of Web tests in the LMS					
7. Ease of online examinations					
8. Delayed LMS resource usage by FIS					
9. Improved identification after integrating FIS					
10. The identification can be faked even after FIS					
11. Enrollment difficult for biometrics					

Where: 1. Very Inappropriate, 2. Some Inappropriate, 3. Neutral, 4. Some Suitable, 5. Very appropriate

Similarly it must keep in mind that the results of the questionnaires are based on:

- Sample of 80 students
- Advanced technical knowledge
- Average age: 30 years
- Second career or professional experience for over 3 years
- Degree: Industrial Engineering

VI. CONCLUSION

The integration and testing of fingerprint identification system in the learning management system and its development during online test is the line of research that we want to continue and evaluate the advantages and disadvantages in platforms increasingly extensive and highly diverse. As well as studying the responses of students to new technologies in learning platforms.

This new module is targeted for technical profiles with advanced knowledge in emerging technologies. This provides initially greater acceptability and low skepticism about its value. After the test of the module in real exams must do a deep study about the results, producing a feedback and improving to achieve low failure rates as well as a broad acceptance and a possible extension to other technical areas within the university. As the initial approach is oriented to conduct tests online, it is intended that this resource can be integrated as middleware between protected resources, so it is attractive to think of integration in access to virtual and remote labs.

ACKNOWLEDGMENT

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A Virtual Photovoltaic Power Systems Laboratory

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***Abstract*—This paper describes the design and implementation of a virtual laboratory for photovoltaic power systems based on the Cadence PSpice circuit simulator, which is intended to be a complement to the traditional physical laboratory in undergraduate photovoltaic engineering courses.**

Keywords-component; photovoltaic power systems; laboratories; simulation; engineering education; pspice;

I. INTRODUCTION

Virtual laboratories are recognized as an attractive complement to traditional engineering laboratories. Among other advantages, they do not require expensive and dedicated equipment, reduces the required time for instruction, and promote student involvement and learning [1]-[2]. This paper describes the design and implementation of a virtual laboratory for photovoltaic (PV) power systems based on the Cadence PSpice circuit simulator. For this purpose, a library of PV components has been developed, which allows simulating the behavior of PV components and systems.

The use of PSpice is very common in industry, research, and also for training and teaching electronics [3]-[5]. Besides, despite PSpice is a circuit simulator, it has been also used for simulating other kind of systems [6]-[8]. Its application for the simulation of PV systems begins in the nineties [9]-[10], and there is even a textbook on this field [11]. The simulation tool described here was former designed for research purposes [10], but it has been updated as educational software that can be integrated into PV systems engineering courses, which are every day more frequent in the university curricula.

Regarding its implementation, the virtual laboratory is intended to be a complement to the traditional physical laboratory. In this approach, students can be firstly tasked with virtual pre-laboratory assignments, which provide adequate background and preparation before performing actual experiments. Secondly, just in the physical laboratory, students can compare measurements and simulations during the experiments. And finally, the virtual laboratory can also support post-laboratory tasks allowing the repetition of experiments or the completion of unfinished laboratory exercises. Besides, in any of these steps, students can gain a deeper understanding of the matter through the design, simulation and analyses of their own experiments.

Among the prerequisites that should have evaluated before the adoption of computers for instructional use [12], accessibility and student computer background have received special attention. Regarding the former, a free version of the PSpice simulator is readily accessible to students without the need of purchase the license. Besides, the full license software is usually available in departments that teach courses on PV power systems. Regarding the second prerequisite, students of electrical engineering usually have learned PSpice before boarding the PV laboratory. Anyway, the required technical skills for the students are basic and they could be taught at the beginning of the course.

II. LABORATORY DESIGN

This section presents an overview of the virtual laboratory design and the simulation procedure. Later, several examples of application are shown.

A. Symbol library

A symbol library of PV components, so-called Sisifo, has been created in PSpice using a two-level hierarchical design and following a bottom-up method [13]. At the bottom level, PV components are described by mathematical models. Next, a schematic is created for each mathematical model by means of equivalent electric circuits using the Analog Behavioral Modeling feature provided in PSpice [14].

For example, the current-voltage (I-V) curve of a PV generator can be expressed with a good approximation by a single exponential model [15]:

$$I = I_{SC}\left(1 - \exp\frac{V + I R_S - V_{OC}}{N_S V_t}\right) \qquad (1)$$

Where I_{SC}, $V_{OC,}$ R_S and N_{SM} are, respectively, the short-circuit current, the open-circuit voltage, the series resistance, and the number of cells connected in series in the PV generator. The thermal voltage V_t is equal to mkT_C/q (where m, k, T_C and q are, respectively, an ideality factor, the Boltzmann's constant, the temperature of solar cells, and the electron charge).

A simplified bottom schematic that describes the electric behavior of (1) is displayed in Fig. 1, which is composed of a current source (IL) equal to I_{SC}, a voltage-controlled current source (IDIODE), and a series resistor (RS). The schematic has two output terminals (VG+ and VG-), and two inputs (irradiance, G, and ambient temperature, T) that define the operating conditions of the PV generator, of which depend the variables I_{SC}, $V_{OC,}$ and V_t that appear in (1).

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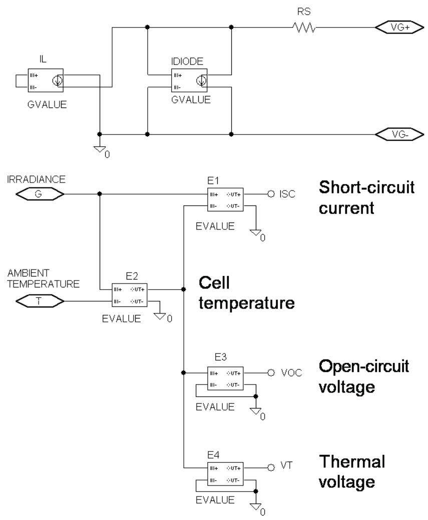


Figure 1. Bottom schematic for the PV generator.

At the top level, each schematic is associated with a hierarchical symbol that can be electrically connected in a photovoltaic system. For example, Fig. 2 displays the symbol of the PV generator associated with the schematic of Fig. 1. Each symbol has a set of attributes that define some parameters of the mathematical model, which can be modified by the students. For example, table 1 shows the attributes of the PV generator, which can be directly obtained from manufacturer's datasheet.

Besides the PV generator, other system components have been created from mathematical models using the Analog Behavioral Modeling: ON/OFF series charge regulators [15], lead-acid batteries [16] and DC constant power loads [17], whose detailed description can be found elsewhere [10]. For example, Fig. 3 shows all the Sisifo symbols arranged for simulating a Solar Home System.

The two-level hierarchical design of Sisifo allows using the simulation tool in beginning, intermediate and advanced laboratories. In the first ones, students can simulate experiments previously designed by teachers, as in Fig. 3. In intermediate laboratories, students can simulate their own experiments only at the system level considering each component as a "black-box" represented by its hierarchical symbol, without the necessity for a deep knowledge of the underlying mathematical model. In advances laboratories, students can move down in the hierarchical design in order to analyze the models or even fit model parameters as a function of the experimental measurements. Besides, advanced students can also create new models and symbols for enlarging Sisifo.

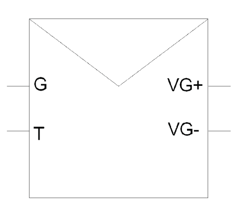


Figure 2. Hierarchical symbol for the PV generator.

TABLE I. ATTRIBUTES OF THE PV GENERATOR SYMBOL

Attribute	Definition	Units
ALFA	Short-circuit current temperature coefficient	$ºC^{-1}$
BETA	Open-circuit voltage temperature coefficient	$ºC^{-1}$
ISCM	Module short-circuit current	A
NOCT	Nominal Operation Cell Temperature	ºC
NPC	Number of cells in parallel (per module)	
NPM	Number of modules in parallel	
NSC	Number of cells in series (per module)	
NSM	Number of modules in series	
PMM	Module maximum power	W
VOCM	Module open-circuit voltage	V

B. Simulation procedure

Once Sisifo has been created, it is added to the list of symbol libraries available in the Cadence Schematics environment, which allows designing and drawing PV circuits, as in Fig. 3, simulating them using PSpice, and analyzing the waveform of simulated data using a graphical interface called Probe [13].

Regarding the simulations, PSpice supports three different types of analysis that are very useful for the virtual PV systems laboratory:

- DC sweep analysis. It allows varying the value of a source (voltage or current) or a parameter through a specified range, which can be used for plotting the current-voltage curve of a PV component, for depicting the variation of a model variable as a function of a given parameter (e.g., I_{SC} versus G), and so on.
- Transient analysis. It allows the simulation of a PV circuit response as a function of time, from an initial state (time=0) to a specified time.
- Parametric analysis. It repeats one of the two previous analysis (DC sweep or transient) several times varying the value of a source, or a parameter, in each iteration.

Next section shows some examples of simulation with PSpice using these types of analysis.

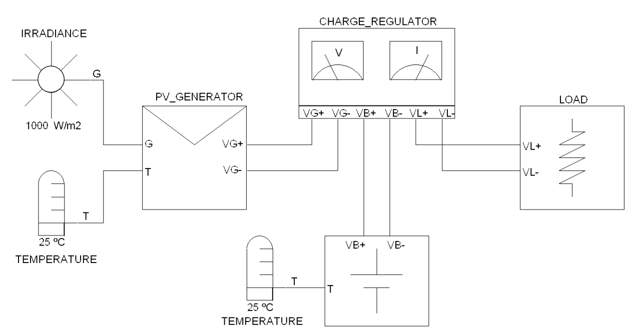


Figure 3. All Sisifo symbols arranged for simulating a Solar Home System.

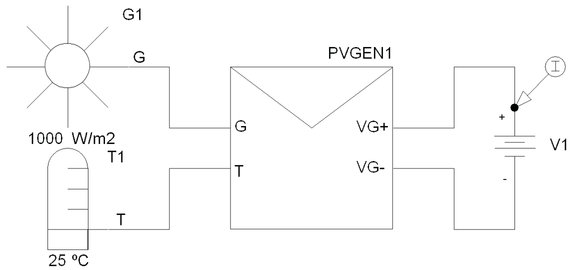


Figure 4. Circuit for simulating current-voltage curves of a PV generator.

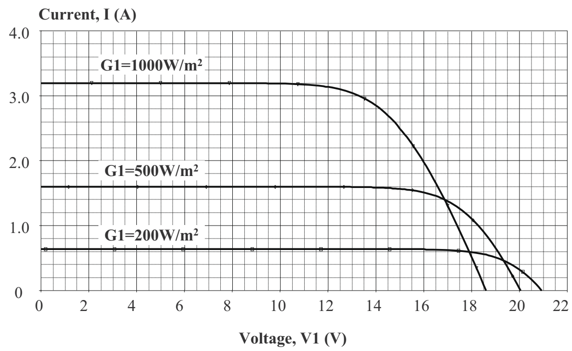


Figure 5. Current-voltage curves from the circuit displayed in Fig. 4.

C. Simulation examples

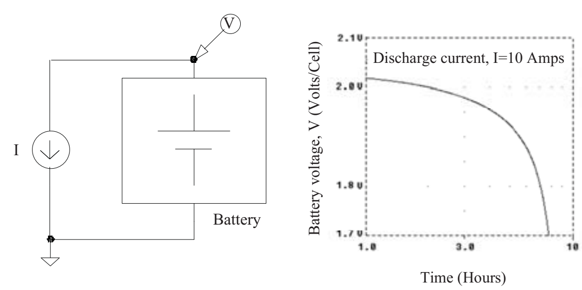
This section illustrates some of the possibilities of the virtual PV power system laboratory through several examples of simulation.

1) PV generator current-voltage curves

Figure 4 shows the circuit for simulating the current-voltage curve of a PV generator. Figure 5 displays the simulation results after performing a DC sweep analysis of the voltage source V1 (from 0 to 22V) and a parametric analysis for three irradiance values of G1 (200, 500 and 1000W/m^2).

2) Battery voltage-time discharge curve

Figure 6-a shows the circuit for plotting the voltage-time curve of a 2V/100A·h lead-acid cell, which has been simulated for a constant discharge current of 10A using a transient analysis. Figure 6-b displays the simulated curve.



(a) (b)

Figure 6. (a) Circuit for simulating the discharge curve of a battery. (b) Voltage-time curve at a constant discharge current of 10A.

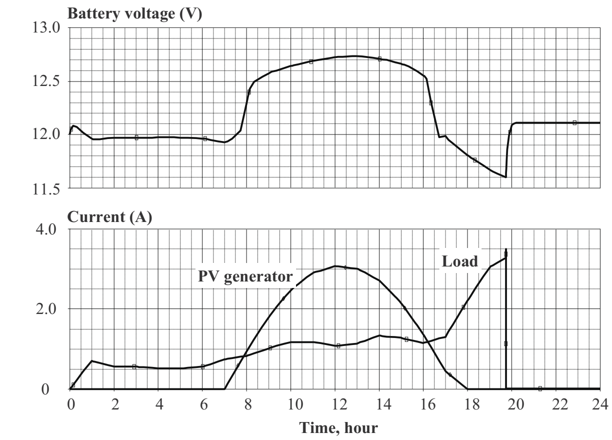


Figure 7. Evolution of the battery voltage, PV generator and load currents, after performing a transient analysis of the circuit displayed in Fig. 3.

3) Transient response of a photovoltaic system

Figure 7 displays the evolution of the battery voltage, as well as PV generator and load currents, after performing a transient analysis of the circuit shown in Fig. 3.

III. IMPLEMENTATION

In general, it is agreed that computer simulations can not completely replace physical experiments [18]. Following this approach, the virtual laboratory has been constructed as a complement to the traditional laboratory. This section describes the application of the virtual laboratory in supporting pre-laboratory and post-laboratory assignments. Despite the virtual laboratory could be also used during the physical laboratory session for comparing measurements and simulations, this application has been not considered here because the available time for hands-on experiments is usually scarce.

A. Pre-laboratory assignments

Exercises of simulation within the PV virtual laboratory can be introduced in pre-laboratory assignments required to students. Such exercises may provide a theoretical background to the behavior of PV power systems before performing hands-on experiments.

Pre-laboratory assignments may include not only a set of simulation tasks but also quizzes that should be given to the instructor at the start, or before, the physical laboratory session, which can be employed for identifying points of confusion or individual student problems.

Obviously, the designed of the set of simulations should be adapted to the student level. In their basic form, simulations may be performed on straightforward circuits previously designed by instructors, as in Fig. 4 and Fig. 6-a. Students should just push a button and the results of simulation appear in the screen, as in Fig. 5 and 4-b. Students can also modify some parameters of the circuit, for example changing the discharge current in the circuit of the Fig. 6-a, repeat the simulation, and analyze the results. A simple, but essential, application of these circuits is analysing the current-voltage curve of a given component, for example, as in Fig. 5.

Pre-lab simulations can also reproduce the behavior of hands-on experiments, which may provide an adequate preparation to students before starting the physical laboratory. Anyway, students must be aware that simulations are based on simplified mathematical models, which have their limitations in terms of accuracy, and therefore they only provide an approximation to the behavior of real PV components and systems.

B. *Post-laboratory assignments*

The virtual laboratory can also support post-lab tasks allowing the completion or the repetition of hands-on experiments, which is one of the main limitations of the physical laboratory.

Simulations also allow performing experiments that are very difficult of carrying out in the physical laboratory because they require a lot of time. For example, the measurement of one battery discharge curve, as in Fig. 6-b, lasts several hours or days, depending on the battery capacity and on the discharge current. Other experiments are simply impossible of performing in the physical laboratory. For example, determining the variation of the battery capacity as a function of the discharge current requires the measurement of several discharge curves, which would last weeks or even months.

Besides, in both pre and post-laboratory assignments, students can gain a deeper understanding of the matter through the design, simulation and analyses of their own experiments. Finally, it is worth mentioning that simulations can also play the role of assistant for answering pre and post-laboratory quizzes, which can be linked to simulations for this purpose.

IV. CONCLUSIONS

A virtual photovoltaic power systems laboratory based on PSpice has been developed and presented in this paper with the aim of promoting and improving student learning in this engineering field. For this purpose, a PSpice symbol library of PV components, called Sisifo, has been constructed, which nowadays includes the following components: PV generators, ON/OFF charge regulators, lead-acid batteries and DC constant power loads. The current version of Sisifo allows the simulation of these individual components as well as stand-alone PV systems created with them, and it is free available in Internet [19].

The virtual laboratory is intended to be a complement to hands-on experiments and can be used in supporting both pre-laboratory and post-laboratory assignments. Pre-lab exercises may provide theoretical background and preparation before performing hands-on experiment, and they can also be employed for identifying points of confusion or individual student problems. Post-lab tasks allow the repetition of hands-on experiments or performing those that are very difficult of making in the physical laboratory.

An evaluation of this virtual laboratory will be implemented in order to assess the students perception of its effectiveness on their learning process, whose results will be presented in a future work.

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PSpice, PSpice Schematics, and Probe are registered trademarks of Cadence Design Systems, Inc.

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Lab2go - A Repository to Locate Educational Online Laboratories

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Abstract— **This paper discusses the creation of a common framework to describe online laboratories according to the semantic web technology. The so called Web 3.0 technology is actually growing daily and is proposed to be one of the leading Web technologies within the next years. Improved search mechanisms and facet based browsing are only some key features which enhance the data handling within the repository. Online laboratories are interactive experiments which are available over the Internet and can be divided into two main groups, software simulations and laboratories made up of real hardware equipment. Technology-enhanced learning is becoming a new important trend in higher education worldwide. In particular, engineering education is becoming an exciting emerging field of research because it involves a multitude of disciplines which aim to resolve the pedagogical problems that arise with the advancement of technology. With the help of the semantic web technology a significant step forward can be made in terms of a general description model for online laboratories and the location of laboratories with requested properties.**

Online Laboratory; Semantic Web; Ontology; Web Repository

I. INTRODUCTION

With the excessive supply of broadband Internet at the end of the last decade many research groups all over the world have started the exploration of ways to support and facilitate the learning activities of students by using new possibilities. Important outcomes of these efforts are online laboratories. Since nowadays many modern universities, schools and other organizations started programs to offer, in addition to their traditional laboratories, a wide range of online laboratories in different scientific fields. Like traditional laboratories this type of laboratory provides students with particular engineering experience and allows them to explore systems and their real behaviors. Online laboratories are fundamental for home experimentation because they are especially designed for distant learning students to acquire introductory hands-on experience and familiarize themselves with real-life phenomena. These online experiments can be found in different fields, including electronics, mechatronics, informatics, etc [1].

In traditional laboratories most of the equipment is not efficiently used because of the fact that the laboratories are used for other experiments or very specific equipments are only used for a very short time period of the year. Online laboratories are a suitable instrument to solve these problems by sharing the labs. Since some years there are a number of initiatives to share laboratories among different institutions by the use of a common architecture such as the iLab Shared Architecture from the MIT (Massachusetts Institute of Technology) [2].

Currently, available online laboratories are often hidden from the public education community. The most significant reason for this problem is the current lack of information about online laboratories that provides potentially interested parties the ability to search for adequate laboratories. This lack of information regards almost everyone in the online laboratory community such as students, administrators as well as lecturers even if this influence them in a different manner. The fundament of this problem is the lack of information which describes the resources. This is not a specific problem of online laboratories but rather a general problem of the current Web and concerns many content types of special interested communities. A solution to solve this problem can be realized by using Semantic Web technologies to describe these content types, establish a framework and create a base for new searching mechanisms. This paper discusses the creation of an online laboratory portal in the form of a repository, where information about specific properties of these laboratories is collected. The basic idea behind the Web portal is a semantically linked repository for the e-learning community that reduces the efforts of researchers as well as lecturers and students to find and share information about online laboratories all over the world.

II. ONLINE LABORATORIES

Online laboratories are interactive experiments that are provided over the Internet. Online laboratories can be divided into two main groups, software simulations and laboratories made up of real hardware equipment.

Figure I describes the classification of laboratories in general. Our focus is the right field of the depicted.

Software simulations are often used in the field of mathematics and in particular simulations where either the setup of hardware is too expensive or the setup of a laboratory is too difficult or even impossible, due to security reasons. Simulations help students to improve their knowledge and an approximate idea of the behaviour of the "real" world [1].

A large amount of currently used software simulations are already Web based and thus allowing learners to get access to these laboratories at any time and from any place[1] .
Web-based software simulations are so called "Virtual Laboratories" and differ from remote laboratories in that way, that they only use software while “Remote Laboratories” consist of real hardware equipment. In comparison to “Virtual Laboratories” remote laboratories allow persons to manipulate real hardware. Because of the fact that laboratory experiments and instruments are becoming increasingly sophisticated and expensive for universities to purchase and maintain remote laboratories is getting more and more interesting. Remote laboratories

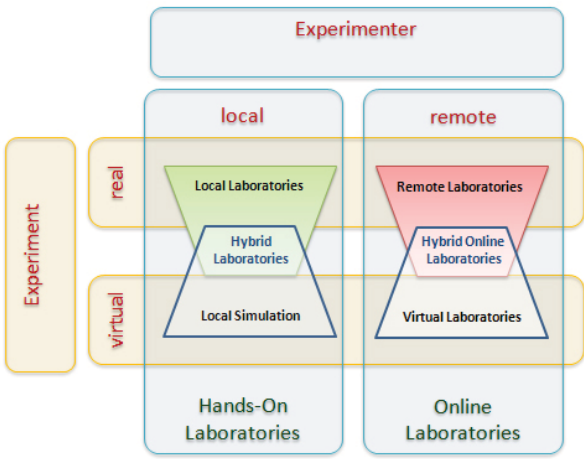

Figure 1. Classification of Laboratories

offer a solution and represent a practical alternative through which students may conduct experiments online, regardless of time and space limitations. Compared with traditional laboratory practice, remote laboratories offer flexible learning in time and place, access to a wide number of distributed experiments and cost-cutting strategies. Furthermore, as collaborative educational strategies become more widespread, remote laboratories offer great possibilities for students to interact as they work towards a common goal.

III. SEMANTIC WEB

At the beginning, the Web consisted basically of many Websites containing only unstructured text. Web 2.0 extended this traditional Web with a few extremely large Web sites specialized on certain specific content types like YouTube for Videos and Flickr for pictures. The transition from Web 2.0 to Web 3.0 implies a growing transition from receiver to producer of information, from static to dynamic content, from control of the few to the wisdom of the crowds. In contrast to Web 2.0, in Web 3.0 many Web sites will be hosting arbitrarily structured content what will be realised by using Semantic Web technologies.

The fundamental characteristic of the Semantic Web is the description of various content or information with metadata. In the traditional Web anyone can write a page saying whatever they please and publish it to the Web infrastructure. In the case of the Semantic Web, it means that our data infrastructure has to allow the individual to express a piece of data about some entity in a way that it can be combined with information from other sources. This sets some of the foundation for the design of RDF (Resource Description Framework) [3]. It means also that information is not managed for a large corporate data center.

The Semantic Web standards have been created as a medium in which people can collaborate on models that they can use to organize the information and share models that can be used to advance the common collection of knowledge.

The Semantic Web also uses the idea of class hierarchy for representing commonality and variability. Differently to OOP (Object Oriented Programming), Semantic Web is not focused on software representation, classes are not defined in terms of behaviours of methods, although the notation of classes remains and plays much the same role. Higher level classes represent commonality among a large variety of entities and lower level classes represent commonality among a small, specific set of things [4].

This is the essence of modelling in the Semantic Web: providing an infrastructure where not only can anyone say anything about any topic, but an infrastructure that can help a community work through the resulting chaos that is present on the Web concerning different viewpoints about a determined subject [4]. A model can provide a framework (like the described classes and subclasses) for representing and describing commonality and variability of viewpoints when they are known. But, in advance of such an organisation, a model can provide a framework for describing what sorts of things we can say about something.

The Resource Description Framework (RDF) is a W3 Consortium recommendation used today as a general method of modelling information by different syntax formats. The idea of RDF is a metadata model that describes Web resources in the form of subject – predicate – object expressions. This form is called triples in the RDF terminology. The subject denotes the resource and the predicate denotes the aspects of the resource and express a relationship between both.
Another important document of the W3 Consortium recommendation is the RDF – Schema (RDFs) which enables the description of so called lightweight ontologies.

IV. BASIC DEFINITIONS OF THE ONTOLOGY

One of the first steps to make use of the semantic web technology is to create an ontology, or in other words a generalized, formal representation of the domain. This general model consists of various properties, data types and relationships representing various types of online laboratories in a generic model. To develop a model, which is accepted by the end users it is essential that the model is easy to understand, well structured and a very close representation of the real world situation. At this point several discussions about various general states have to be made to ensure that the model is really applicable to the current real-world-situation.

When starting with the model definition, a lot of questions about very principal things come up. For example how is an online laboratory defined? Should we differ between an experiment and a laboratory? These fundamental questions are very important and only with the right definitions of the basic description model, it can maturate in the right direction.

Because of the various possibilities and terms to describe this domain, a general definition of the basic terms and principles in an online laboratory grid is required. In our general definition the following terms and definitions are used to describe an online laboratory:

TABLE I - PROPERTIES OF AN ONLINE LAB

Property	Description
Access URL	Every online laboratory has a URL (Unique Recourse Locator) which gives access to the online laboratory directly or via a middleware. In the last case, different laboratories can have the same access URL if they are connected to the same middleware and one laboratory can have one or more access URL if it is connected to different middleware.
URI	The property URI is the Unique Identifier of the Online Lab.
Name	The property title describes the name of an online laboratory which has not to be unique. (An online laboratory can represent in different languages).
Experiments	The property experiments represent virtual and real experiments of online labs.
Owner	The property owner represents a person or an organization (like universities or companies) which offers the online lab.
Administrator	The property Administrator represents a person which is responsible for the online lab.
Creator	The property Creator represents a person which is the developer of the online lab
Description	The property description is a textual description about the online laboratory without semantically linked data which is available in different languages.
Languages	The property language represents the available languages of the online lab.
Release date	The property release date represents the release date of the laboratory
Access Requirements	The property access requirements will give information about the access of the online laboratory (open access, access upon request, restricted access)
Lab Status	Defines whether the laboratory is online or offline.
Costs	This property represents the access costs
Technical Data	This property provides information about the technical background for the online laboratory developers
Client Requirements	This property provides information about requirements for the clients. (Client Technology, Runtime engine, Client OS, Browser)
Documentation	Documentation of the online laboratory including Hardware and Software
Architecture	This property describes the architecture that a specific laboratory belongs to.

/

Online Laboratory

An online laboratory is an environment which allows a person to perform experiments and or simulations over the Internet. Online laboratories consist basically of software based simulations or hardware based experiments.

An online laboratory can be divided further in the following three types of labs:

Remote Laboratory

A remote laboratory is an online laboratory which provides real experiments. This definition implies the control of real hardware and the realization of real measurements.

Virtual Laboratory

A virtual laboratory is an online laboratory which provides software simulations or applications.

Hybrid Laboratory

A hybrid laboratory is an online laboratory which combines virtual laboratory and remote laboratory technologies. It provides real hardware experiments and software simulations as well. All types of online laboratories have several properties, which are described more in detail in Table I.

As already mentioned an online laboratory can have one or more experiments. An experiment is defined as follows:

Experiment

An experiment in the current domain is defined as the smallest enclosed unit of an online laboratory. It provides the execution of virtual or real experiments to observe the behavior and output of a system. An online laboratory consists of one or more experiments in different fields of science and engineering.

Moreover according to the interactivity between experiment and experimenter an experiment can be categorized further:

Observation Experiment

The experiment parameters as well as the experiment environment are fixed. This kind of experiments allows users only the observation of an experiment.

Fixed Experiment

The experiment environment is fixed but the experiment parameters are remotely tunable. Furthermore it is possible to control one or more measurement instruments also remotely.

Adaptive Experiment

The experiment parameters as well as the experiment environment are remotely changeable. This definition includes for example the modification of a circuit.

Every experiment of an online laboratory is described by certain properties which are defined in Table II.

V. TERMINOLOGY

For the terminology existing vocabularies and bindings were inspected more in detail. The focus was on several well known standards such as Dublin Core [5], LOM [6], SKOS [7], vCard [8], FOAF [9] and WGS84 [10]. With the analysis of the various standards it could be seen that mostly only parts of the standards can be adopted and that a definition of various new terms for the definition of an online laboratory model is required.

TABLE II - PROPERTIES OF AN EXPERIMENT

Property	Description
URI	The property URI is the Unique Identifier of the online laboratory.
Name	The property title describes the name of an online laboratory which has not to be unique. (An online laboratory can represent in different languages).
Type of Experiment	The property type of experiment describes the type of the Experiment (Virtual experiment or Real experiment)
Description	The property description is a textual description about the experiment without semantically linked data which is available in different languages.
Scientific Field	The property field represents the division of the experiment like engineering, science as well as their subdivisions like electronics, mechatronics …
Educational level	The property educational level represents the current educational level (primary, secondary, tertia, research)
Creator	This property represents a person which is the creator of the experiment.
E-learning material	This property informs about additional e-learning material for the experiment
Difficulty level	This property represents the level of difficulty of the experiment.
Online lab	An experiment is part of one online laboratory. This property represents these online laboratories.
Documentation	Documentation of the experiment including Hardware and Software
Duration	The time a user needs to complete the remote experiment.

After the evaluation of the different standards it was made the decision to adopt basic terminology and data types from Dublin Core to the model. Examples for adopted terms are such as *title*, *description* or the *type* data which are also defined in Dublin Core.

It is not planned to make use of SKOS and LOM in the online laboratory description because only small parts are fitting to the current model and can be used to describe the online laboratory domain.

It was therefore decided to adopt some basic terminologies from the not included standards. An example here is the property difficulty from LOM [6]. This property describes very well the difficulty level with a pre-defined range [Very Easy, Easy, Medium, Difficult, Very Difficult].

Besides describing all technical aspects of the laboratory itself, a model to describe persons, organizations and projects has to be found. This will be used for properties like creator, administrator or rights holder. As already mentioned vCard and FOAF were inspected more in detail. The decision was to make use of the FOAF ontology because on one hand it allows more possibilities to define relationships between agents and on the other it is much more used as vCard in RDF representation. Within the portal it would be very useful to see which person knows whom. It facilitates then the organization and establishment of connections with other persons and groups of researchers more easily.

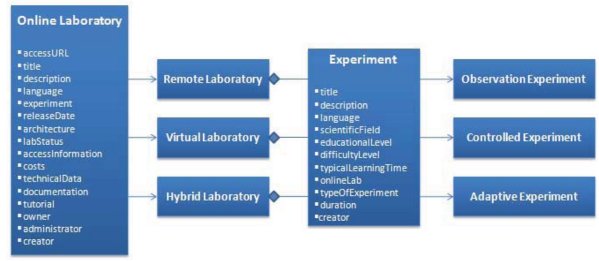

Figure 2. Classification of Laboratories

VI. ONTOLOGY DESIGN

The first milestone is to develop an ontology which is easy to understand and to apply. Right now for the first approach the ontology includes only fundamental descriptions and properties which are not too detailed. It is advisable not to implement a too detailed description at the beginning, so that the users have some freedom and the model can grow with additional user's feedback regarding inputs and terminologies. With this practice a creation of an ontology which can't be understood and would not be accepted by the end-user could be avoided. It is a very important point in defining a description model for a domain, as it could help users to get in touch with the description model and gives them also the possibility to contribute to the model development, what might increase the acceptance of the model by the users.

According to the basic definitions which are described in section IV and on the use of standard vocabulary described in section V the first draft of the ontology was made. Before starting to build the ontology a class diagram for the model was designed.

As can be seen in Figure 2 we used two main classes to describe an *Online Laboratory* and an *Experiment*.

The online laboratory class contains all properties which were defined in table II. The different types of laboratories are designed as subclasses of the online laboratory class. Depending on the type of experiment each subclass is linked to one or more experiments of a specific type. Furthermore, a class of type remote laboratory can be linked only to experiments where the property *typeOfExperiment* is set to "Real experiment".

The *Experiment* class contains all properties which are described in table II. Additionally three subclasses were created to determine whether the experiment is an observation, a controlled or an adaptive experiment. With this further division it is easier for users to differ between the interactivity types of experiments. To differ trough various interactivity types also a further property in the class *Experiment* could be used, but in terms of model readability and the implementation of facet based browsing it is much better to make use of subclasses.

Afterwards the software Protégé [9] was used to design the ontology itself. Protégé is a freely available tool to design ontologies. It has a lot of useful plug-ins and extensions such as the reasoner *Pellet* to check the ontology's consistence and the *Property Matrix* plug-in make the ontology design easier. That plug-ins will help through the development process.

As already mentioned above, the idea is to let the ontology grow together with user inputs. It is now questionable how this can be realized? We assume that users would not send e-mails or insert various comments in a forum if they have any improvements. Therefore next to the definition of the properties in our ontology the user has the possibility to add additional information. This will be realized similar as in Wikipedia. The user could write additional descriptions by setting tags. The evaluation and analysis of these tags will give the developer very useful hints to find out which additional properties are desired by the end users. Afterwards it is apparently which tags can be adapted to the model as a new property or also which properties can be renamed that they are used in the proposed way.

VII. The Aims With the Lab2go Repository

The basic idea of the Web portal is a repository that offers a common framework to collect and describe laboratory data from different laboratory providers located all over the world turns out to be necessary to continually foster the development of laboratories and exchange of knowledge among interested parties. This Web portal will host information about running research projects, researchers, organisations, existing state of the art technologies, etc, in order to strengthen the collaboration in this field of science as well as providing knowledge about the laboratories and their operating institutions.

To solve this problem this paper shows the fundamental problems that exist today and the resulting requirements which are necessary to implement a successful platform. One objective of the platform is the improvement of the search process for online laboratories with the use of Semantic Web technologies. Due to the particular way used by the Semantic Web to describe resources, not only full-text search can be supported. This kind of description enables new ways for the implementation of search mechanisms like facet based browsing which allows the user to search information according to the properties of a special object. Furthermore it is possible to query resources based on specific criteria. To outline the differences between the well known Web 2.0 methods and the Semantic Web a typical information searching scenario can be used:

- A user wants to search for all online laboratories which contain experiments in a specific filed, have a specific difficulty level and are freely available.

Using today's available Web searching tools such a query is not possible as these tools make use of keywords to perform a search. On the other hand such a scenario is perfectly supported by the Semantic Web. This new possibilities provided by the Semantic Web is one of the important keys to advance the information exchange in the community.

The fundamental concept of this project is based on the idea of making use of already existing solutions. Therefore the semantic collaboration platform OntoWiki which was developed by the research group AKSW at InFAI (Universität Leipzig, Institut für Angewandte Informatik) was chosen. OntoWiki is an open-source Platform which can be installed by any Web space and accessed by an ordinary Web browser [11] and is easily adjustable by writing customized plug-ins. Differently to MediaWiki [12], the base platform of Wikipedia, where the metadata can be directly included into the text, OntoWiki is completely based on tags and can be called as a data wiki.

OntoWiki is the base for the portal and provides a framework for the development of Semantic Web application and was therefore used to create a customized solution for online laboratories. Mostly users are not familiar with the concepts of Semantic Web or are not willing to spend time writing the metadata manually. For that reasons Lab2go is also a tool to create metadata for the online laboratory resources.

VIII. Ontology Design

The focus of this chapter is to figure out the main functionalities which will be available within the lab2go repository.

Every user has the right to browse through the repository content and search information about online laboratories. With a free registration a user gets the rights to add, edit and evaluate content. When creating or editing a contribution, the user can set group policies to control the level of access other users have over it. In terms of evaluation there are the possibilities to rate and to comment a resource. With this functionality a user gets a better feeling of the relevance of a resource.

A significant new functionality is the searching possibility. As already explained in the previous chapter by using facet based browsing customized views can be generated. Property values can be filtered out from a list of resources. This so called filtering can be applied to any type of resource and also to any relation within the description model. With a combination of two or more filters the list of results becomes more precise. Another possibility is to display various properties directly in a resource list that the property values can be recognized very quickly.

To manage the data easily an editor and additional plug-ins were developed. It looks like a common html-form when entering new laboratory data or changing some contents. In the backend the data is converted automatically to metadata and then saved in the store. Features like auto complete for pre-defined property values or resource names (if already existing) make the data input more comfortable. Also visual inputs like a calendar or the possibility to add multiple values of a property makes the editing of resources easier.

Additionally to the pre-defined description model a user can set individually tags for each resource. This has the advantage that in case a user wants to describe his laboratory with a specific term or property he has the freedom to do this without any limitation. In a second stage exactly these tags can be inspected and evaluated. The result represents a significant input for the ontology development. Misuse of terminology and need for additional terminology could be detected easily.

Not only searching, evaluation and data management tools were implemented in lab2go. One of the most important key points remains as in so many applications the data handling. Filter out data which is not interesting for certain views; finding the right order of the displayed information and make use of an impressive style are only a few considered key points. The developments in this field are going on continuously.

CONCLUSIONS

Semantic Web technology is a very broad field that can be applied in many distinct areas. In this paper very specific use-case scenarios are mentioned. There exist however many other possible extensions beyond the main scope described here. It proposes an approach on how to provide such specific type of information using Semantic Web technologies, and comprehends a first implementation attempt of an open source platform.

Summarizing this paper shows an overview about the Semantic Web (Web 3.0) and the most important differences to Web 2.0. Furthermore it covers the problems of lack of information channels for online laboratories and presents a potential solution in the form of an online portal.

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Session 10D Telefónica Special Session: Telefonica University Chairs Network

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LMS and Web 2.0 Tools for e-Learning: University of Deusto´s Experience.Taking Advantage of Both
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Attracting Student Vocations into Engineering Careers. EnginyCAT: Catalonia Promotional and Prospective Plan
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The LULA Project by the Telefónica Chair of the University of Extremadura - LULA Linux Distribution for Latin American Universities
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***Abstract*—This panel session proposal describes an introduction of the technical activities carried out by some of the Telefionica University Chairs along Spain in a whole view of activities inside the social working of Telefonica and their associated chairs.**

Keywords-Technical networks, Corporative identity.

Abstract

Telefónica University Chairs Network focuses on the social impact of Information and Communication Technologies (ICT) in the public agenda issues and especially in some of the principal areas of interest for Society, such as: the impact of ICT in education, health, inclusion, climate change, security or productivity. In 2009, its strategic plan includes: research projects, prospective studies and surveillance technology, workshops with experts and knowledge transfer activities. Currently, there are 16 Telefónica University Chairs in 13 Spanish universities.

Under this programme, Telefónica has promoted a knowledge portal that aggregates information coming from different universities sources belonging to the Chairs network. The objective is to create and develop a community of experts belonging to both, the academic and the business worlds with the aim of opening the conversation and disseminate the contributions to the community. In the website can be found, for example, information about the use of new technologies in education, advances in telemedicine, analysis about how to improve the industry productivity or how the use of ICT can help with climate change challenges.

Telefónica University Chairs Network provides a channel for knowledge transfer among universities and also between universities and Telefónica. Specialised workshops are periodically organized with the participation of business and university experts to discuss and share knowledge about the current state and the future of some strategic topics. Some of them are: the new architecture and the challenges of the next Internet generation, IPv6, intelligent sensors networks and security in electronic commerce.

More information: http://www.catedras.telefonica.es/

LMS and Web 2.0 Tools for e-Learning:

University of Deusto´s Experience Taking Advantage of Both

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Abstract— **Information and Communication Technologies have enabled us to gather much more information, to process it better and to disseminate it to anybody in the world. So, these technologies appeared to be one of the most powerful tools for educators. The experience or the University of Deusto in applying a Competence-Base Learning Model supported in an LMS and the results of the adoption of this Learning Model to a new Open Source LMS give us the lights of LMSs experience in University. The adoption of 2.0 technologies in the classroom through an initiative of the Telefonica Chair has result in a test bank and a very useful experience for educators interested in applying these technologies so as to know the lights and the shadows of this tools.**

Keywords-component; education; LMS; Web 2.0; Learning Cycle; Competences; e-Learnine.

I. New Technologies in Education: a Mirage or a Miracle?

Are Information and Communication Technologies bringing any good to Education? This was the question which UNESCO began with its Newsletter on Education in the end of 2003. They wanted to pinpoint that it was a chimera to trust in any single technology to transform education [1], more than that, we would like to add that a bunch of well chosen technologies could hardly produce any good result if they are not properly backing an effective pedagogical framework.

In fact, having the best means and the best technologies does not always turns out in obtaining the best results if those means and technologies are not guided in the right direction.

Most of the experts would agree with us in thinking so. Information and Communication Technologies have enabled us to gather much more information (and under some conditions, to transform it into knowledge), to process it better and to disseminate it to anybody in the world (of course, if that one has granted the access to the net). But technologies, by themselves, will not give us a place in heaven.

II. MAUD: The Pedagogical Framework of University of Deusto. A Competence-Based Learning Model

The University of Deusto, a pioneer in this field, has been developing and implementing a unique pedagogical framework during the last ten years, known by its acronym MAUD (University of Deusto´s learning model) [2], which has been the foundation of the Tuning Project [3], now spread not only around European Universities (and supported by European Commission) but to the United States and South America ones as well. MAUD is based in autonomous and meaningful learning and centered in students´ skills and competences development as advocated in the European Higher Education Area.

The development of a competence-based model found in ICT a natural ally allowing teachers and students bear part of their interaction and monitoring of their learning process in an Learning Management System platform.

The Chair of Telefónica has been involved over last two academic years in several projects related to the use of information technology as supporting tool in the learning process, two of which are presented in this paper.

III. MAUD: Learning Cycle

MAUD encourages students´ personal development and meaningful learning. Meaningful learning cannot be based merely on the acquisition and repetition of information that has been delivered by someone else. To this effect, meaningful learning should involve thinking, combining activities of observation and contextualization with activities of reflection that help to understand situations and contents. Thus, MAUD [4] defines a structured learning cycle organized in five stages, as shown in Figure 1.

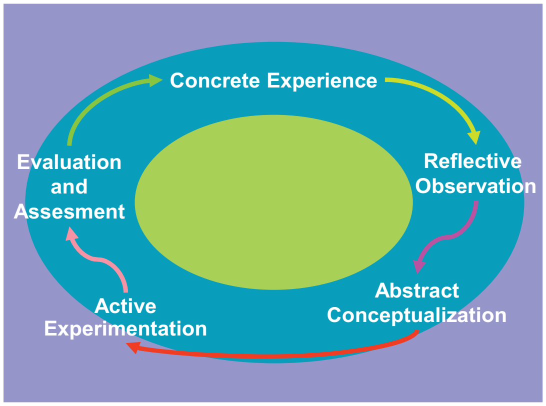

Fig.1 Learning Cycle Stages

A. Concrete Experience

To sum up, this first step tries to put the student in relation with the topic to be learned/studied starting from her knowledge and experienced got beforehand. People do not begin learning form point zero, but from the standpoint of their own knowledge and experience. Therefore, the model seeks to motivate the student through his own experience and context to come close to the idea of the topic. During this step, defining or describing the problem under study and sharing the objectives of the training process between professor and student are key issues.

In this first phase of rapprochement there can be introduced various strategies to assist the person to ask the proper questions to contextualize a particular subject: Linking to other contexts, experiences, future expectations, questions of how to learn, questions on the subject, common perceptions.

B. Reflective Observation

This phase is an essential step in meaningful learning. Reflective observation involves knowing how to see, opening our eyes to look at the reality that surround us and, secondly to question through reflection the considerations that this observation, in the form of ideas, objectives, goals, experiences, contents or conducts, really means.

It is the student who takes the responsibility of linking ideas, feelings and values with their own reality and way of seeing the world. Learning materials are the basis of student work, and must represent a challenge for them to transform their knowledge and previous experience in new and deeper understandings.

This phase should help learning things and concepts, their use and applications, their effects on others, and so on. The purpose of this phase is the person to ask questions, be concerned, as no significant learning can occur if individuals do not question about what they are learning and their circumstances. Evidence shows that students have great difficulty in asking questions and questioning about themselves and their surroundings. This is a clear indicator of excessive dependence from their teachers.

C. Abstract Conceptualization

Abstract Conceptualization follows Contextualization and Reflection. Then, the purpose is to learn as deeply as possible the theoretical positions on the issue, bringing the student the theory that from a specific scientific area has developed. Conceptual learning is based on the acquisition of knowledge, scientific terminologies, facts and data, methods and strategies, principles and theories that shape scientific knowledge of each subject.

This is a learning process based on the use and application of cognitive skills such as understanding, analytic-synthetic thinking, critical opinion and divergent thinking, enabling integrated and meaningful learning.

The conceptualization phase allows the scientific mainstream and, at the same time, it is a phase that helps the mental structuring of ideas, principles and theories, linking them with other ideas and thoughts that help to embed information and especially to produce knowledge.

The conceptualization of coping may be an individual at an early stage and later as a team. The contribution of intellectual styles and individual characteristics of each member are the basis for enrichment of the group.

D. Active Experimentation

The fourth phase concerns the linking of theory and practice. It includes any activity that promotes development of skills and abilities of students in applying concepts, theories or models with the aim of further strengthening them. There can be included drills, exercises, projects, or research designs.

It is an especially appropriate stage for collaborative work, learning to cooperate and develop social and interpersonal skills. This individual and social nature of learning has the potential to create powerful learning environments that use traditional and virtual experience as a resource for collaborative learning and to integrate academic and social life. In this regard the contribution of an LMS and, as discussed in subsequent experience, Web 2.0 happen to be a very powerful element.

E. Evaluation and Assessment

This final evaluation of the results achieved in the learning cycle has several perspectives. A staff assessment for the students to reflect on what they learned. A formative dimension that is based on the consideration of feedback as the key to student progress. Finally the evaluation of work and study of each student as an accountability process.

IV. ICT IN EDUCATION: LEARNING MANAGEMENT SYSTEMS AND WEB 2.0 TOOLS

As everybody knows, the boom in ICT has fostered the development of virtual education or e-learning, above all, to gain efficiency in the new paradigm of Higher Education as it is been promoted by most states in Europe. Among them, Learning Management Systems –or Content Management Systems- and those architectures related to the Web 2.0 are the most popular tools to make virtualization in education possible [5].

But these advances in information technologies have produced, as well, great controversy in the education community about the ideal model, whether it is a LMS or anything based in Web 2.0 architectures, to support in the most appropriate way the learning model. Deusto was not outside of this discussion and that is why from the Chair of Telefónica some projects in both directions were proposed in order to provide tools and guidance on their use that were helpful to teachers and students in developing the learning process.

V. A LMS TO REINFORCED MAUD

According to a recent study carried out by the California State University (23 campuses, 450.000 students, 47.000 people in staff) about "The state of Learning Management in Higher Education Systems", at least in USA, LMS based in proprietary software are, to a large extent, the most used solutions to virtualize the learning-teaching process. [6]

Maybe because of the same way of thinking, maybe because human being likes to create new things, the first development of MAUD at University of Deusto was based on an e-learning platform built ad-hoc for the University, called "ALUD". The decision of developing a specific tool, based in proprietary software, rather than adopting an existing one (even under Open Source Code) was due to the primary objective to adopt of an e-learning platform perfectly adapted to the conceptual framework of the own learning model so that it would guide and support the work of educator, not only in development, but in the very conceptualization of her subjects.

More recently, the opportunity of adapting the well-known Open Source Learning Management System, Moodle to the MAUD was analyzed. It should offer educators a platform widespread in the educational community, and therefore it should be easier for them to share and to exchange courses and materials while a suitable environment to learn the conceptual model they use.

The aim of this project was twofold. For one hand, University of Deusto took advantage of this process to rethink the whole tool (ALUD 2.0 was born) and for the other, it was agreed that the new solution should be an Open Source based Learning Management System; so, in this way, it was Moodle the new LMS chosen.

It is to be said that, from the perspective of the University of Deusto´s Model of Learning (MAUD), two key elements should be added to Moodle in the customization process of the new platform: the format of the courses according to the definition of the learning cycle and competency assessment.

A. Format and Structure of Courses

The previously stated Learning Cycle makes up the different learning units, so the five phases described before define the structure of each learning unit. To accomplish to the model, Moodle Themes were used to support the learning units.

In this way, every instructor could use the new LMS platform without having to renounce to any characteristic of the Deusto´s pedagogical framework. Another aspect that was no of less importance was the fact that, achieving a structured model, it would give higher coherence and solidity to the whole educational system as everybody would have to adopt the same strategy in the teaching-learning process.

Besides of that, the use of Moodle for the new ALUD 2.0 platform offers educators a variety of compatible resources through the incipient/vast community of teachers that are developing courses with it, so that they can exchange units, courses and, even, teaching strategies with the rest of the users of Moodle based LMS.

A special effort had to be made in order that all the previous educational material, the one designed under the first proprietary platform, could be automatically migrated to the new one as no teacher wanted to lose her work. This was a key issue for the success in the adoption of the new platform.

B. Competence-based Assessment

As Delors´ report proposed [7], during the last years, a special attempt has been made to redefine education as a process to acquire and develop some general and specific competences instead of following with the old paradigm which defended to learn (memorize) a lot of different contents. As explained before, this is the main foundation of MAUD.

Competences are the cornerstone of Deusto´s pedagogical model. By competence, MAUD understands: "the set of acquired knowledge, capacities, abilities and skills leading to a good level of development and action" [8].

Twenty one competences comprise MAUD´s framework, each of them split in three progressive levels of achievement and for every level several indicators and descriptors have been established to offer a complete vision of students´ performance.

Being the development of these competences the main goal of the MAUD, assessment plays a fundamental role in the whole model. As most users know, Moodle contains a special module to assess outcomes which could be used, if not as it was, for this purpose.

Moodle´s "standards" offer some sort of indicators and descriptors to define somehow competences. Nevertheless, these resources were not sufficient to back competences as they are defined in MAUD up.

So it was necessary to adapt the new LMS to MAUD´s requirements. To accomplish it, the arranged module allows to structure competences in different levels, indicators and descriptors. It is platform administrator's or each educators job to define and concrete each of those aspects for the given competence or competences that should be developed through the particular subject. After this work of systematization, evaluation could be done to know the real level achieved by each student related to every worked competence.

The result of this work has been a new platform that has integrated the knowledge accumulated in a decade of research and experimentation in a competency-based model over an Open Source platform widespread in the educational community.

Currently a pilot experience is been developed for a score of ALUD experienced teachers who are evaluating the functionality of the new platform, its adaptation to the latest innovations in the model as well as the migration process.

First impressions are excellent and the experience has been so positive that some of the technicians who have been involved in the adaptation of Moodle have decided, encouraged by the university itself, to create a startup to use the knowledge gained in the project and, in this way, to extend it to the broader community of Moodle users.

In this process, there has been an important contribution of some professors associated with the Chair of Telefónica not only through their technological knowledge of Moodle developments but the experience in applying Moodle and The Pedagogical Framework of University of Deusto. Finally, complete content and organizational editing before formatting. Please take note of the following items when proofreading spelling and grammar:

VI. LMS VS WEB 2.0 : TWO OPPOSING POINTS OF VIEW

During the last decade, LMS deployments have been consolidated in most of the traditional educational institutions [9], not only to replace face-to-face instruction (e-learning), but also to combine it with computermediated instruction (b-learning or "blended learning") [10]. No problems have been found by teachers and students adapting to this change -apart from the usual technical difficulties- because these systems mimic most of the concepts used by traditional education: order, arrangement, standardized evaluation, etc.

At the same time, the popularity of Web 2.0 [11] has brought a slew of new interaction styles, boosting participation (collaboration), customization (flexibility) and immediacy (real-time). Such a radical shift has determined the development roadmap for other available platforms, forcing their adaptation to the new communication demands.

Unfortunately, traditional e-learning platforms are too lined up with the conventional education structure. They haven't been able to follow flexible 2.0 applications' fast pace. Some teachers, fascinated with this new conception of the web, have decided to rebel against the imposed LMS and embrace the Edupunk movement [12]. Edupunks criticize the stifling rigidity of the archaic and closed LMS systems, reclaiming more open, agile and flexible platforms, focused on the learner instead of the content, by using a DIY ("Do It Yourself") approach. Despite the critics, Edupunks are not alone in the crusade against LMS.

Recently, Bush and Mott stressed this point [13] with a "Post-LMS Manifesto". Are we witnessing a shift from formal to non-formal education? From education institutions to education experiences? In the late 90's Gatto complained about many absurd and anti-life situations related to traditional education systems [14]. Nowadays, many authors reclaim a ubiquitous education [15][16], on-request and nonformal[17], an "expanded education" [18]. As Stephen Downes stated [19], "learning is not based on objects and contents that are stored, as though in a library. Rather, the idea is that learning is like a utility -like water or electricity- that flows in a network or a grip that we tap into when we want". Is this just another top-down versus bottom-up endless debate? The Cathedral versus the Bazaar? [20] Or an intergenerational conflict caused by different views of the world and the learning process? [21] It remains to be seen whether the Web 2.0 Connectivism will oust the Constructivism, theoretical principles of popular LMS like Moodle.

VII. EDUCATION 2.0: A POSITIVE EXPERIENCE

Despite the successful experience of the University of Deusto in the use of an LMS as a tool in which support their learning methodology, the Chair of Telefónica, true to its goal of exploring the opportunities offered by new technologies applied to education, could not stop the implementation of 2.0 technology in the classroom.

That is why we chose to prepare and offer students a course based on knowledge of these technologies and, in turn, developed the intensive use of them as an educational tool.

After two years promoting them, we could conclude that using Web 2.0 applications at classroom has been a very positive experience. The main advantages of this change are the following:

A. Less lectures, more collaborative work

Unidirectional communication and the lack of spontaneous interaction are common situations when teaching large classes (above 50-60 students). This trend can be broken easily with social software: prompting students to comment their opinions in blogs, following each other in microblogging networks or using them to interact with teachers. Education 2.0 is more than just adding technology to education. Teachers have to become DJs [22], combining miscellaneous sources and keeping their students on the dance floor. Content can be self-made, remixed -using someone else's material- [23], or even created by the students themselves.

B. No textbook

Instead of working with just a sole information source, several diverse resources are used: blogs for group work, microblogs for communication, RSS feeds, multimedia clips linked from a wide range of platforms (e.g. Youtube, Flickr, SlideShare) and a wiki to gather them all in a common place and support collaborative work (see Fig. 2).

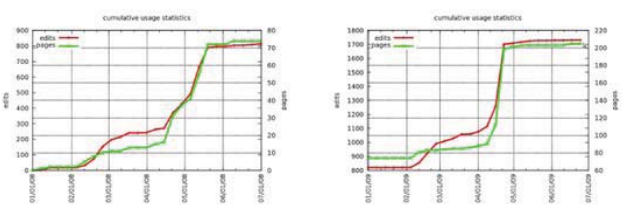

Fig.2 Wiki use during Spring Semester 2008 and Spring Semester 2009

Personal blogs or tumblelogs are used as virtual portfolios to store all subject-related resources created by teachers, students or any other online content service provider. Students can organize these Personal Learning Environments (PLE) freely, without being evaluated.

C. Beyond physical boundaries

Education extends beyond the spatial and temporal boundaries of the classroom. Interaction is not limited to teachers and students, it is virtually global. This new scenario brings back the old question quoted by McLuhan and Leonard

[24]: "Why should I go back to school and interrupt my education?". Forty years later, we can solve this problem.

Moreover, two interesting consequences arise:

- The teacher is not the only yardstick anymore: aside from their evaluation within the classroom, students also receive feedback from other users interacting with the contents.
- The teacher is not the only available data source anymore: collective intelligence of social networks [25] replaces the expert's role. Not only students are the subjects of their own learning, but also the sources of learning, functioning as the perceptual input for the wider network.

D. Non-formal communication, non-formal learning

Not every student is able to discuss a topic in public, but they are usually experts on texting and sending thoughts by mobile phones. Microblogging platforms such as Twitter are based on a similar idea. Therefore, not much training is needed to use them and increase spontaneous interaction. Microposts can be shown during the class, in a less formal way of real-time participation. If lack of privacy is a problem, less public services like Yammer or EdModo can be used instead.

As we can see, it is not casual that many teachers are gradually introducing Web 2.0 tools in their learning processes [26], due to their multiple advantages.

VIII. NOT EVERYTHING IS SO POSITIVE

Web 2.0 features can also be considered problems in certain contexts. Where some see flexibility, others see lack of control; where some see cooperation, collaboration and syndication of several sources, others see confusion.

These are the main problems detected during our experience:

A. Lack of order

Course content is not stored in a centralized and static location anymore. Instead, the content generated by teachers and students is scattered over the Internet, and may be compiled. Not being able to find and organize these resources will result in a limited vision of the whole working material. Therefore, developing this digital competency becomes mandatory [27], mastering RSS aggregation and social bookmarking platforms. In our case, we consumed RSS feeds created with Yahoo! Pipes, using blog widgets as clients, for aggregating all subject-related content.

B. Lack of control

Teachers lose control at two different levels:

- Technical level: control over technical infrastructure is usually lost using Web 2.0 platforms, because most of them rely on "cloud computing" based free services. Although is possible to deploy them "in-house", both Google and Microsoft are offering free professional services to academic institutions (regarding email, IM, VoIP, blogs, microblogs, sites, documents, etc.). The bad news is that service providers disclaim any liability or responsibility for any loss. Recently, popular Web 2.0 services experienced temporary failures, being some of them fatal to their users. [28]
- Social level: the etiquette of the Internet cannot be controlled by teachers. Their authority means nothing outside the academic institution. Spam, Internet trolls or even cyber-bullying can disrupt teachers' efforts, without an easy solution.

C. Privacy and arbitrary limits

Web 2.0 platforms promote participation and new content publication, but they usually forget about privacy issues. Mediocre or incorrect information can remain accessible on the web for years, lasting after the end of the author's academic career, and becoming a problem during professional life. Out of context blended-learning activities or teenagers' opinions may lead to similar problems. Besides, these platforms can add arbitrary restrictions to their Terms of Service (TOS), blocking some uses that can be considered legitimate by teachers. A clear example of this problem is the arbitrary age limit for some social networks, preventing their use in lower grades.

D. Scope confusion

Analyzing students' preferred social networks (e.g. Facebook, MySpace) and using them to deploy educational content is very tempting for many teachers, but such strategy doesn't seem to be very effective for some reasons:

- Teachers are not students' best option to share spare time with. They may take it as an invasion of privacy, so it is not recommended to try to be best friends.[29]
- Such an environment specifically designed for leisure, hyperconnected with procrastinating friends, full of silly tests, chats, etc., is not the best place to work on educational content. Moreover, previously defined digital identities within each social network can alter online teacher-student relation.

IX. RECOMMENDATIONS FOR WEB 2.0 ADOPTION AS EDUCATION SUPPORT TOOLS

There is no specific solution for the problems mentioned before, but different tools can be combined to achieve a good trade-off among them. The solution we would like to propose is based in a combination of content-centered tools, typically managed by teachers, and learner-centered tools, managed by students:

- Course wiki: installed on a local web server, with restricted access for students (control, privacy). Teachers and students use them to support collaboratively generated content, in a structured way, compile links to remote resources and practice with wiki syntax (Wikipedia contributions sandbox).
- Group blogs: created in a public service and merged together in a blog planet. Students use them to create and share subject-related content.
- Personal blogs or tumblelogs: used as virtual portfolios or PLEs. Students freely choose their favourite service

to develop them, and select the RSS feeds generated by the rest of the tools.

- Microblogs: mostly Twitter (public, universal) and Yammer (private, under control), to encourage spontaneous participation and real-time communication inside or outside the classroom. Generated microposts are easily added to blogs through RSS widgets.

Since there have been no previous similar experiences in our Faculty, some confusion is understandable at the beginning of the semester, but students should be able to understand the dynamics of the work after a few weeks.

The use of more homogeneous systems could be another solution to the problem. The structure of the content can be hold in a LMS supporting Web 2.0 features (e.g. Moodle), managed by teachers, and integrated with a virtual portfolio platform (e.g. Mahara). In such systems students can organize, discard or add resources in a relevant way to their own learning process, interacting with a wider community and adapting the structure of the network as their experience varies [30].

X. Some Conclusions

As previously stated, there is a serious debate when it comes to selecting appropriate tools to improve the e-learning platforms.

From University of Deusto´s standpoint, there are some consequences that have come clear during our experiences. First of all, our efforts to develop our own pedagogical framework pay off; not only to improve the previous teaching-learning process, but to design the proper tools to implement it from the technological point of view.

From University of Deusto´s standpoint, there are some consequences that have come clear during our experiences.

First of all, our efforts to develop our own pedagogical framework pay off; not only to improve the previous teaching-learning process, but to design the proper tools to implement it from the technological point of view.

Secondly, Learning Management Systems still can provide a variety of good results for professors and pupils and keep things "structured". cbconc

Thirdly, Moodle –the Open Source Solution- has provided a proper environment for our LMS ALUD 2.0. It is flexible enough to be adapted to our own needs and requirements.

Fourthly, Web 2.00 tools have happened to be a good mate in this journey. Being clear about the objectives, one can use both approaches and tools instead of choosing between both of them.

Nevertheless, there is nothing that lasts forever. For us, it means that from the Chair of Telefónica and, of course, following the path we are building up, we will keep on experimenting, implementing, and fortunately, developing suitable tools and technologies to help education to be the process that any student deserve and every teachers need.

Acknowledgment

The findings and conclusions presented here are the result work of many professors and lecturers from Deusto and especially to the Vice Rector for Innovation, Aurelio Villa, and people from the Institute of Educational Sciences at the University of Deusto. The support of Telefonica through the Telefónica Chair has allowed parts of this work to be carried out and news experiencing been developed nowadays in the adoption of new technologies into the classroom.

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Attracting Student Vocations into Engineering Careers

EnginyCAT: Catalonia Promotional and Prospective Plan

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Abstract—**In the developed countries vocational demand for scientific and technical studies is a serious concern for government, universities and companies and different analysis and programs are promoted to try to compensate the steady decrease of their demand. In this communication the phenomena for Spain, with an spatial emphasis in Catalonia, will be reviewed in the European context, and some clues for promoting new engineering vocations will be given.**

Keywords-component; engineering vocations, engineering studies promotion

I. INTRODUCTION

The Catalan Government concerned by the decreasing number for engineering vocations in the context of a foreseeable mid term increase on engineering graduates demand to sustain the so called knowledge-based society new challenges decided to promote a plan to foster engineering vocations in Catalonia, through the EnginyCAT initiative. Progress and output figures for high school and university have been analyzed and compared at international level and more significant insights on youngsters' vocations and clues for attracting vocations have been studied.

UPC-Telefonica Chair on Future Trends on Information Society focuses its activity on the analysis of the Information Society evolution and in its impact on the different significant social fields and in particular on education, health, administration and competitiveness. Special attention is devoted to the national and international best practices and indicators at both national and international levels. The research approach for the different fields is based on the analysis on the general trends at global level and its projection at local level based on specific regional studies that allow extracting robust indicators. One of the main topic consists on studying the evolution and future trends of the scientific and technical education at the different educational levels and more particularly in high education at both national and international perspective

EnginyCAT and the UPC-Telefonica Chair have joined efforts to study the main professional fields and factors for engineering practice are to draft the main professional tendencies. Basic trends for job market will be analyzed at international level and projected into the national and regional Spanish levels. Specific and differential parameters for the job market corresponding to the different main disciplines: civil, industrial and ICT, is a central field of research.

II. ACADEMIC AND PROFESSIONAL CONTEXT

In order to have a consistent perspective about higher educational demand on engineering and technology it seems convenient to take a look at the preceding pre-university secondary education, Fig. 1, [1-2], data in science and technology areas.

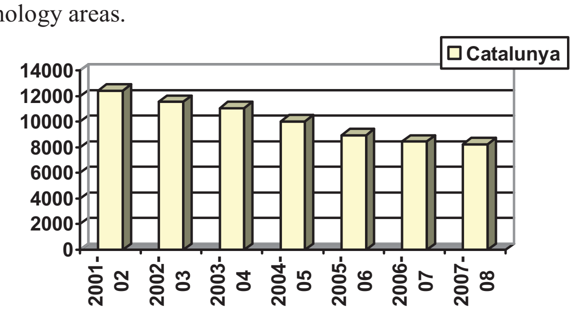

Fig.1 Number of technology junior-year high school students in Catalonia

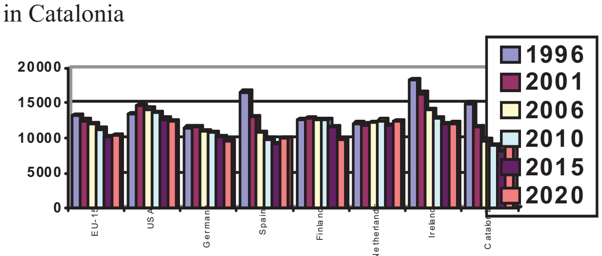

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Fig. 2. 18-year old population evolution per million of country inhabitants.

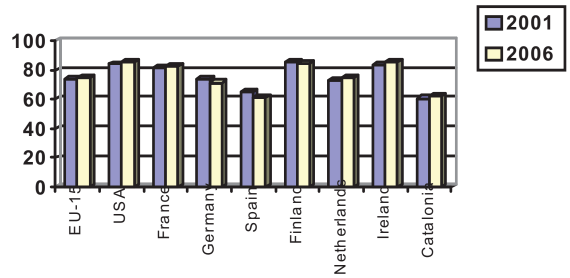

Fig. 3 Percentage of population successfully completing secondary school

At Catalonia (and similarly Spanish level) data show, [3], a steady yearly decrease of about the 5% (2% due to the demographic decrease and the 3% due to the percentage decrease with respect to its population of age). In absolute terms the population has passed from 12.400 youngsters in 2001-02 to 8.243 in 2007-08 academic year. When looking at the evolution into the international context, it may be seen, Fig. 2, that demographic decrease will still add pressure to the total demand decrease at least until 2015. An additional factor stressing the number of students entering at higher educational level is the percentage of youngsters completing secondary school. It may be seen in Fig. 3 how these percentages for the Spanish and Catalan cases are 15-20 percentage point below European averages.

Finally a last significant aspect contributing to the engineering studies vocation shortage is the percentage of women going into Science and Engineering studies. It may be seen, Fig.4, how the percentage of women is around 25-30% far below the "natural" 50%. If some studies as Biology and Architecture are extracted, the percentage fall below 20%.

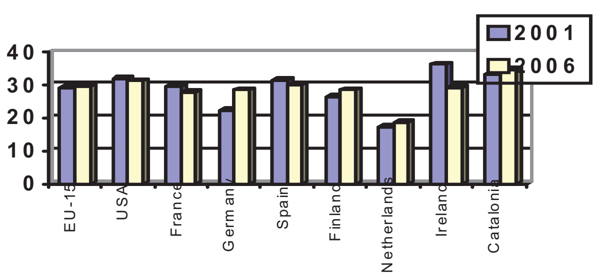

Fig.4 Population percentage Science and Engineering higher education women presence

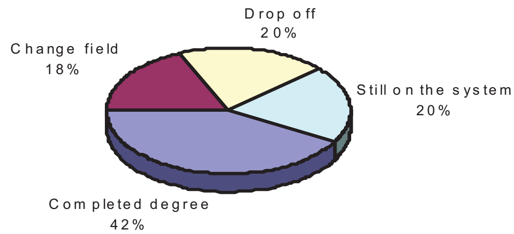

Fig. 5. 2000-07 follow-up of 8.700 university engineering students in the Catalonia University system

Once entering into the higher education, [4-7], engineering studies tend to be relatively difficult studies and the graduation rate is in some cases really low. Fig. 5, shows the academic evolution of a cohort of students entering into engineering studies in Catalonia and their evolution after 7 years (largely enough to have completed their studies). Results show, that eve entering with good marks in general, in average 60% of the students will probably complete their degree (20% probably with a quite longer time than necessary), 20% will switch to different university systems and 20% will drop off from the university system. In Fig. 6, comparative international results show that the situation in quite similar in mostly of the countries except in very well organized systems as the Ireland (Anglo-Saxon) and France systems.

When looking at the occupational job market, Fig. 8, it may be seen that in general the number of necessary professional engineers and technicians to attend the so called knowledge based society is normally above academic output and this shortage will foreseeably increase in the coming years. As an example, for the Catalan case, Fig. 8, the actual number of existing professionals (98.000) is slightly below companies demand (110.000) this makes a shortage of 12.000 graduates (10%. approximately). With the actual number of yearly graduates 7.600 out of 13.000 students entering the university this shortage will increase up to 25.000 when compared to the average EU-25 or up to 55.000 when compared to the number of professional engineers and technicians of the top European countries.

It is then clear the urgent need for reducing the gap.

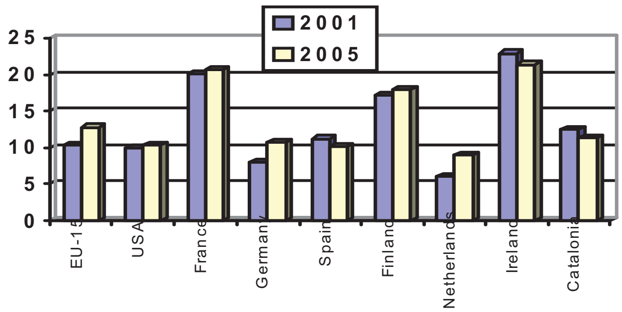

Fig. 6. Science & Engineering university graduates per 1.000 20-29 year old inhabitants

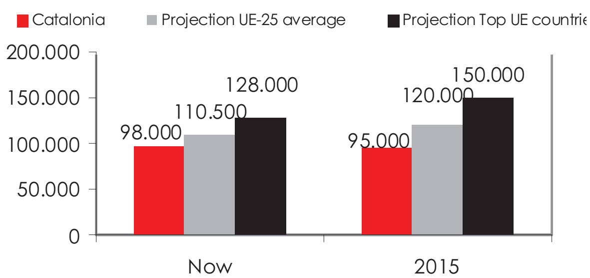

Fig. 7. Number of professionals now and 2015 projection for the engineering professional occupational market in Catalonia. Source CEDEFOP and EnginyCAT processing [8]

III. ENGINERING YOUTH PERCEPTION

In order to act over the system it is necessary to understand the factors behind the vocational shortage phenomena. Mostly of the factors are qualitative perceptional elements [9], Fig. 9, shows the more significant reasons expressed by the European youngsters to explain their lack of interest towards the Science and Technology studies.

Among the different aspects: atracttivity, difficulty, salaries and interest express their perception of a low return for a significant effort. In short they do not feel the social return (not just or especially in terms of salary) is consistent with their personal investment.

In order to contextualize this question, Fig. 9, shows the perception comparison for different professions.

It may be seen for example as Medicine studies even when having many common threats in terms of effort with engineering studies are perceived much more positively than the engineering studies.

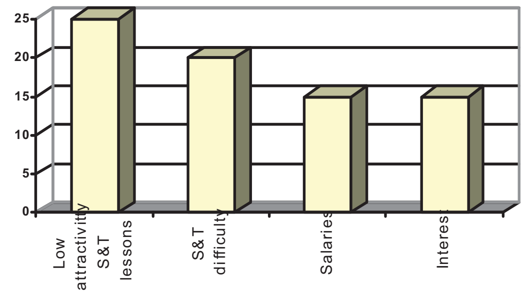

Fig. 8 Percentage of European youngsters marking the different reasons to express their lack of interest towards Science & Technology studies.

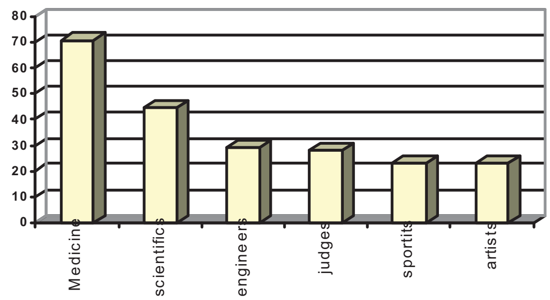

Fig. 9. Percentage of European youngsters positive perception of different professions.

IV. ENGINYCAT A PLAN TO PROMOTE THE ENGINEERING STUDIES IN CATALONIA

To balance this situation different aspects will need to be addressed. Three points will be critical: to attract more youngsters to the S&T studies, to improve the graduation rate at both secondary and university levels, and specially to improve the matching between the graduate expectations and the social return. Starting late 2008 the Catalan Government, through the University and Research Department created a plan, EnginyCAT, to promote engineering studies among Catalan youth. The goals of the program, Fig. 9, where addressed towards three main focus:

- To improve the scientific education among secondary education.
- To increase the number of youth vocations to pursuit science and technology studies, addressing a special attention to the women presence.
- To contribute to he improvement of the graduation rate at university level, with a special effort towards the engineering and technology curricula modernization.
- To improve the matching at both quantitative and especially qualitative levels between the engineering and technology graduates and the professional demand.

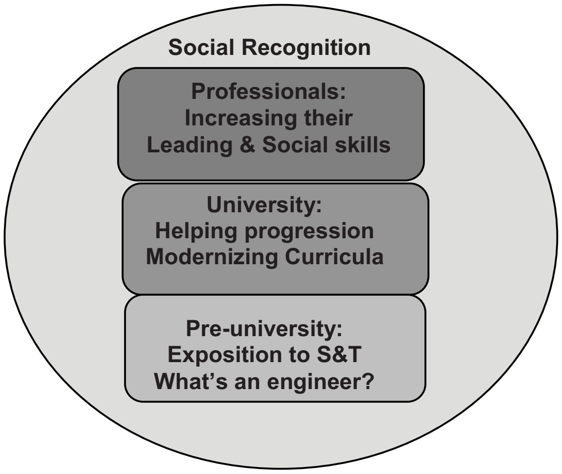

Fig. 9. The main goals of Promotional Plan EnginyCAT

The different actions need to be strongly coordinated with the different agents already operating in the system as universities and higher education institutions, professional charters, companies, etc, to create synergies and avoid duplicities.

The program consists on a broad scope limited number of actions to cover the three main areas of interest, pre-university youngsters, higher education (engineering and technicians) and professional insertion as described in Table I.

LÍNE 1: What engineers do?	
	ACTION 1: VÍDEO Engineering Presentation (Youtube format)
	ACTION 2: Engineering Studies Thematic Guide
LÍNE 2: Explore!	
	ACTION 3: High School S&T Workshops (Robotics)
	ACTION 4: S&T Summer Camp
LÍNE 3: S&T Talent recognition	
	ACTION 5: Pre-university S&T Prize Log
LÍNE 4: Prepare yourself!	
	ACTION 6: Teaching Assistant Mentoring Program
	ACTION 7: Designing future projects
LÍNE 5: Get involved!	
	ACTION 8: Engineering 2020. Curricula modernizing
LÍNE 6: Your future: Innovation!	
	ACTION 9: Leading and Communication skills

Table I. EnginyCAT Program basic lines and actions

V. ENGINNERING CHALENGES AND PROSPECTIVE JOB OPPORTUNITIES

On of the main actual social concerns is job market in general, and youngster's job market in particular. One of the ways to give a clear vision about engineering is through their professional and job new opportunities. The basic point is to translate to the society a fresh idea of the engineer role, not just from its parts but mostly from the point of view of the problems that may solve, Table II, and the job opportunities it may create.

The reasons to become an engineer
Leading a sustainable economic development to solve the emerging social XXI century new challenges
Increasing number of job opportunities and professional outputs
Innovative designs to promote new projects, ideas and companies

Table II. The engineer vision

VI. CONCLUSION

From an attentive analysis of the different academic and professional parameters it comes clearly the need to increase engineering attractiveness among youngsters. Science and technology proficiency will become of the leading economic development factors.

The key element is to generate a clear, positive and realist vision of the future engineering professional role. It is then necessary to interact with the k-18 pre-university kids and youngsters to let them know the new engineering challenges, (energy, water, health, environment, education, mobility, entertainment, aging people, etc), to increase the design and problem-solving component in our higher level studies, and to promote the innovation and entrepreneurship culture among our graduates to contribute too create a new generation of high-added-value companies able to hire very talented and motivated people.

ACKNOWLEDGMENT

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The LULA Project by the Telefónica Chair of the University of Extremadura

LULA Linux Distribution for Latin American Universities

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Abstract—**Many universities use free software applications as tools for theoretical teaching and for resolving practical exercises. In many cases they are software package,s in the development of which many users collaborate, in constant evolution and adaptable to different teaching needs. In Latin American universities there is a growing tendency to use it and there are communities highly committed to its development.**

As an attempt to compile those applications most used in Latin American universities, the LULA Project (Linux para Universidades LAtinomericanas) is about favouring the integration of this software and the exchange of educational material amongst universities. It is a non-profit initiative coordinated by the Telefónica Chair of the University of Extremadura, in which the integrating universities of the Virtual Latin American Campus (CAVILA) collaborate.

Keywords-component; Educational software; LINUX Distribution; LULA Project.

I. Introduction

The Junta of Extremadura (the regional government) was a pioneer in committing to open source software in Spain and, since then has coordinated different initiatives, at both regional and national levels. From the Junta of Extremadura, despite there not being any policy or specific strategy for the implementation of open software sources, it promotes and uses it in many institutional servers. In recent years it has been observed that open source software is being incorporated in different ambits of the Uex. From software used for practice, teaching platforms or web servers and e-mailing. Within the University of Extremadura, the Telefónica Chair of the University of Extremadura (UEx) [1], aimed at teaching and research in Communication and Information Technologies in Universities, is coordinating the LULA project for the creation of a Linux distribution oriented towards the educational ambit.

The idea of this project emerged from the cooperation of the Telefónica Chair of the UEx with AULA [2], an association of Latin American universities (the UEx among them) founded in 2007 and aimed at coordinating the creation of an ambit of higher education in which cooperation and the exchange of knowledge and experiences amongst public universities and research groups Hill be encouraged.

II. The virtual latin american campus as the basis of the LULA project

The Virtual Latin American Campus (CAVILA) is the main initiative of the Association of Latin American Universities (AULA) to boost teaching, research, and Latin American identity by means of cultural diffusion. In this virtual space, the different universities of AULA offer graduate and postgraduate subjects. It is a project which in the last two years has been financed by the AECI (Spanish Agency of International Cooperation).

The Action of the Virtual Latin American Campus aims, in its first phase, at the formation of a joint Teaching Organisation Plan, which is the basic tenet for the overall training of the student, with professional and social relevance, by means of professional crosscutting values training, adapted to the specific problems of their environment. The target group is, initially, the 500,000 students that comprise the Campus of AULA Universities which potentially and directly can benefit more immediately, although an ambitious offer of life-long teaching also exists, for workers and people who, for reasons of distance or lack of sufficient economic resources cannot have access to teaching requiring attendance. In this sense, millions of Spanish-speaking emigrants are being contemplated for whom this could be a great opportunity; women and other isolated indigenous groups could access business training, training or specific retraining courses for employees from their places of residence without the need to travel.

The overall aim of AULA is the creation of a Euro Latin American Virtual Campus of “innovation with social relevance”, with the aim of training committed “workers of knowledge”, as citizens, with human rights, peace and government, along with the solution of regional problems of the surrounding area and business innovation. Thus, it deals with the construction of of virtual space of higher education, with the necessary teaching and research quality, which is possible to achieve sharing the scientific and technical excellence of each university and with the corresponding professional and social relevance.

As for the specific objectives, it should be pointed out that with this virtuality it is hoped that borders will be overcome and the integration of a Euro Latin American university space will be achieved, with multiple human and economic synergies.

Taking these objectives of integration, training, innovation and social improvements as principles, AULA Universities have decided to collaborate in the compilation for the diffusion of open source educational software which is being used in these universities, as an integrating and exportable model for other universities.

III. Components of the LULA project

The LULA initiative is being coordinated by the Telefónica Chair of the university of Extremadura, with the help of those in charge of education and technology at the seven universities which are currently members of CAVILA: Federal University of Santa María (Brazil), University of Guadalajara (Mexico), the National University of Entre Rios (Argentina), the Nacional University of La Plata (Argentina), the University of Porto (Portugal) and the University of Santiago of Chile (Chile). The initial diffusion of the project was to those in charge of these universities, but the news extended in a question of days over the internet to such an extent that other universities and user groups have joined the initiative.

IV. Development of the linux distribution

To create the Linux distribution, teachers of the participant universities, and those which have later joined the project, indicate the educational applications based on open source software which they use daily in theoretical and practical teaching classes. The Telefónica Chair of the University of Extremadura compiles these software packages and studies their suitability and compatibility in order to include them in the LULA distribution.

Since May 2009 the official website http://lula.unex.es is operational with the aim of facilitating communication amongst teachers during the different stages of the project, informing on its present state and offering support services and consultancy to the future users of LULA. This website will also serve as a centre for downloads where any user who desires to may obtain and use a copy of the distribution free of charge, without technical or legal restrictions.

The project has been planned in three phases. Initially, contributions and suggestions are being gathered in relation with the set of applications which will form part of the distribution. The following step consists of creating a preliminary version which can be tested by the teachers who collaborated in the previous phase. Finally, the definitive stable version will be created which will be distributed amongst Universities of CLAVILA and published on the web-site. Three phases are outlined below along with the predicted time span:

Phase 1: Compilation of applications

In this first phase, the participant universities indicate the educational applications based on free software they wish to incorporate in the distribution. An application request service has been set up on the website using web forms as shown in figure 1. Those teachers who wish to apply for the inclusion of applications should previously have a user account. The user register is free of charge and is carried out merely for statistical reasons, in order to know the level of participation and identify the requested applications better.

Figure 1. Application form for LULA applications.

The LULA project is an open project not exclusively limited to the ambit of CLAVILA universities. Any registered user belonging to another university, group of users or private user may suggest the inclusion of additional applications. For this first version of LULA, the application selection process gives greater priority to those applications requested by teachers belonging to CLAVILA universities when necessary.

On compiling applications, the Telefónica Chair will proceed to study and evaluate the suitability and compatibility of requested applications. For each application indicated, the technician will revise licences of use and will carry out installation, functioning tests and a study of their compatibility with the other applications that make up the distribution. The updated list of applications can be consulted in one of the sections of the LULA site (http://lula.unex.es/index.php?seccion=lula). The development of this phase is programmed from 1 June to 30 September 2009.

Phase 2: Creation of trial versions

The aim of the second phase is the development of one or several trial versions of the distribution, commonly termed 'beta' versions. During this phase, the applications indicated by teachers will continue to be evaluated and will give rise to the preparation of specific repositories of the distribution.

The beta versions generated will allow each teacher to see whether the distribution really adjusts to their needs in accordance with the requested applications, or whether, some sort of modification is required before the final version is published. It will also enable any user to try out any one of the educational packages and those of general purpose and check there are no errors or incompatibilities.

Many of the applications included in LULA have binary packages with ready-to-use programmes; however, some requested packages lack these packaged versions, making manual packaging necessary. The integration of LULA specific software in the package management system allows users to easily install and uninstall applications in the system, centralised and with no need to worry about the dependencies that each application requires. The package format *.deb* and the package management system *dpkg* have been opted for in the development of LULA, both of which are characteristics of the Debian GNU/Linux distribution [3].

The launching of the first beta version of LULA is forecasted for 30 October 2009.

Phase 3: Creation of the final version

The aim of the third and last phase is to obtain the final version of LULA, stable, and completely functional. As teachers try out the trial versions and inform on their experiences, the technical team will proceed to carry out any necessary modifications. The causes for change could be related to the repair of errors or *bugs*, the substitution of applications, updating of versions and inclusion of new libraries, dependencies, or preconfigurations. The incidences derived from the use of the distribution's beta versions can be reported by users via the personalised online support service available at the LULA website, or at the email address lula@unex.es. The launching of the final version of LULA, namely, LULA 2009, is forecasted for 15 December 2009.

V. Why create a distribution?

From a technical point of view, all the Linux distribution is made up of a common element, the Linux kernel, surrounded by libraries and applications in the user's space which provides complete functionality to the operative system. One of the main characteristics which differentiates one distribution from another is precisely, the set of applications or packages which comprise it. Originally, each distribution includes a more or less predefined set of packages to satisfy the needs of a particular group of users, giving rise to classification according to purpose.

The general purpose distributions, for example, are usually aimed at home users and include applications of frequent use to carry out basic routine tasks, such as editing documents, surfing the web, watching films, listening to music, downloading contents or sending emails. On the other hand, there is a group of distributions created with specific purposes focussing on concrete aspects such as security, education, entertainment or optimum benefit of the machines resources. The fact of having a wide range of options at our disposal does not guarantee finding the ideal solution for a particular scenario. Moreover, on their being such variety often the task of choosing the best option is made more difficult.

General purpose distributions are very attractive from the point of view that they provide a wide range of packages, the handling of which is relatively simple for home users. What is more, there are normally a considerable number of users or businesses that back and support them. However, a gap may still exist made up of a group of applications not contained in the original distribution and which are required. An initial attempt to solve this consists in integrating the appropriate personal technician in the community of developers of the official distribution, in such a way that it means covering the needs for our concrete scenario from within. Although this is a viable option, the process could prove to be too complex and, more importantly, exceed the deadlines set for the project.

These are just some of the main reasons which raise interest in and the need to create a personalised Linux distribution based on a general purpose distribution. In addition to providing extra required packages, similarly, it would be possible to modify those which are considered to be unnecessary. Many organisations, businesses and user communities find an adequate solution in personalised Linux distributions to cover their needs and objectives. Given the characteristics of the LULA project, it seems that adopting this solution is a suitable option and at the same time justified. However, awareness exists that from nearly any Linux distribution a user with an average working-knowledge of Linux could install the packages that make up LULA but, with the Telefónica Chair having done this previous compilation, selection, running and compatibility tests, this time is saved and enables less experienced users to try out this software.

VI. General characteristics of the LULA distribution

In this section some of the most relevant general characteristics and technical aspects are presented of the Linux LULA 2009 distribution. Given that the project is presently in full development, the possibility of making small changes during the third phase is not ruled out.

- *Base system Ubuntu 9.04 'Jaunty Jackalope' (x86) updated until the launch date of LULA.* In the remasterization of Ubuntu [4] services and applications unrelated to the specific purpose of LULA installed by default have been eliminated in an attempt to reduce the final size of the distribution and improve the overall performance of the system.
- *Execution in Live mode with the possibility of permanent installation in the hard disc.* Currently, the development of an installer called LULA-Installer is being developed, however, its inclusion in LULA 2009 has not been confirmed as yet. The second candidate for installer is Ubiquity [5].
- *LULA specific software packaging*. Manual packaging of applications and libraries in Debian format is generally carried out when the software requested by teachers is not available in the base distribution, or the software version is not that required.
- *Creation of own repositories.* The manually packaged applications will go on to form part of its own software repository kept in the infrastructure of the Telefónica Chair within the University of Extremadura.
- *Java Virtual Machine OpenJDK installed by defect.* This is a free solution which has undergone rigorous compatibility tests, guaranteeing the correct running of the Java applications [6].
- *Wine integration*. Not all the applications that a LULA user could need possess a version for Linux or sufficiently powerful alternatives to replace proprietary

solutions in a given moment. Wine will allow an execution of a great number of native applications of Windows operative systems, in this way favouring the gradual migration from said proprietary platform.

- *Desktop virtualization with VirtualBox*. This software allows operative systems to be installed in virtual machines which can be easily administered.
- *Incorporation of new options in the menu to facilitate the control of certain services.*
- *Visual aspect of LULA. Desktop subjects and icons have been created from original material and resources available on the net under free licences.*
- *Universal and Free technical support service*.

VII. Support and advice service/helpline for LULA users

As element of added value, the Telefónica Chair of the University of Extremadura will offer a support and advice service for LULA users free of charge. The catchment of the service is considerable, given that it would mean approximately half a million pupils that presently make up the universities of CAVILA, plus all those users who wish to use the distribution.

The support and advice service will be offered through a section of the site created specifically for this purpose. Registered users will be able to send all their doubts and queries related to the installation of the distribution and its software packages via web forms. Each query, once resolved by the technician assigned, will become part of the publically accessible data base. The queries resolved will be categorised to help users with silmilar problems find solutions.

VIII. Present state of the project

The Project is developing as foreseen following the content and planning indicated in section IV. The second phase is currently being started. After the call on behalf of the Telefónica Chair to the rectors and other academics in charge of CAVILA universities for collaboration in diffusing the initiative, to date the LULA site has 140 registered users and almost a hundred requested applications during the first phase to be included in the distribution. The number of IP addresses that have visited the site is more than ten thousand.

It should be stressed that, since the beginning of the project, a spontaneous diffusion has been produced through news sites, forums and blogs principally related to Free Software. This has brought about interest in collaborating at other Latin American universities, groups of users and private users. In fact, more than half of registered users identify themselves as being from universities that do not belong to CAVILA.

IX. Some statistical data of collaborations

A total of 95 applications were requested in the first phase, amongst which predominate programming tools, mathematical applications, statistical analysis applications and general purpose applications related to office applications, multimedia and communications. Below, some specific/concrete figures are shown which can provide us with an approximation of the type of application required by teaching staff:

- General purpose applications: 6,3%
- Programming tools: 43,2%
- Mathematics and statistical analysis: 21%
- Educational tools: 7,4%
- Servers: 5,3%
- Other software tools: 14,8%

The nature of the tools requested (listed in figure 2) and the additional information supplied by the teaching staff during the first phase, indicates that a large majority are mainly directed to the teaching and practice of subjects related with programming, ICTs and mathematics.

Figure 2. List of applications requested by users.

Aplicaciones específicas de LULA SOLICITAR UNA APLICACIÓN QUE NO APARECE EN LA LISTA

Aplicación / Librería	*Versión*	*Estado*	*Descripción*
KDevelop	?	Confirmado	Entorno de desarrollo integrado para C/C++
Eclipse	?	Confirmado	Entorno de desarrollo integrado. Preparado por defecto para C/C++ y Java EE
Code:Blocks	?	Confirmado	Entorno de desarrollo integrado para C/C++.
Anjuta	?	Confirmado	Entorno de desarrollo integrado para C/C++.
NetBeans	?	Confirmado	Entorno de desarrollo integrado para aplicaciones Java.
MonoDevelop	?	Confirmado	Entorno de desarrollo integrado para C# y otros lenguajes .NET.
GCC / G++	?	Confirmado	Compiladores de GNU para los lenguajes C y C++ respectivamente.
Protégé	?	Confirmado	Editor de ontologías y framework para bases de conocimiento.
Freemind	?	Confirmado	Herramienta para crear mapas conceptuales.
TkGate	?	Confirmado	Diseño y simulación de cirtuitos digitales.
GNU Octave	?	Confirmado	Aplicación orientada al análisis numérico.
QtOctave	?	Confirmado	Entorno gráfico para GNU Octave.
Python	?	Confirmado	Lenguaje de Programación Python.
PythonG	?	En estudio	Entorno de programación y ejecución para una versión extendida de Python

According to collected data, 82% of users affirm to be familiar with the use of the proportioned free applications, and 66% currently use free applications in their teaching. Another interesting piece of information is the 41% of users who state that they replace some sort of private software for free solutions. The main applications that are replaced correspond to those belonging to Microsoft (Microsoft Visual Studio .NET, Microsoft Office y Microsoft IIS).

X. Conclusions

From the Telefónica Chair of the University of Extremadura, we understand that activities and initiatives that are developed should result in a direct reward for society. In this sense, we relieve that the LULA Project could be of great interest to Latin American university communities in several aspects:

- Students of these universities will have in a single DVD all the compiled software they need for their teaching practice. It is actually relatively easy for a new user of Linux to download and install different educational packages that they may need in their subjects. However, with LULA, as well as saving installation time, they will not need to identify each application one by one and try them out to see if they work correctly, as they will be already installed and ready to use. On the other hand, it is also possible that a percentage of the students and teachers may never have used Linux. In this sense, the LULA Project tries to encourage and facilitate the first encounters with this type of software.

- As for teachers, the fact of knowing what applied education software alternatives for teachers exist could be advantageous and enriching. On compiling all this software in a single distribution, teachers have the opportunity to compare these packages with those they normally use in their teaching. It is hoped that in subsequent versions of LULA work groups will be formed for the exchange of educational material amongst universities.
- Universities which opt for the distribution could benefit from savings in operative system licences and proprietary applications. This philosophy is already being successfully applied in universities and administrations in several countries.

It is still early days to evaluate the results and repercussions of the Project; however, the involvement on the part of teaching staff is good and requests to collaborate are still being received to date. After the first experience, it is foreseen that in 2010 new services and resources in the LULA portal will be incorporated where universities and groups of users of applications or types of specific applications participate in the exchange of material, guides,and experiences, enriching their knowledge and , consequently, of future versions of LULA- For the next version of the distribution the setting up of the most common resources of collaboration in communities of free open code software, such as wikis, forges, mailing lists and, follow-up of task lists.

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Session 10E Area 5: Lifelong Learning and Nontraditional Students - Practical experiences

Experiences in Using Integrated Multimedia Streaming Services to Support E-Learning in Manufacturing Processes

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Influence of PBL Practical Classes in Microcontroller-Based Digital Systems Learning

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TICTAC: Information and Communication Technologies for Augmentative Communication Boards

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Integrating digital video resources in teaching e-learning engineering courses

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Experiences in Using Integrated Multimedia Streaming Services to Support E-Learning in Manufacturing Processes

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***Abstract*— Most E-Learning projects tend to separate learning activities from everyday work. This paper presents an approach where closer integration between learning and work is achieved by integrating multimedia services into manufacturing processes.**

The goal of E-Learning services integration in manufacturing is, through the development of new multimedia solutions, to accelerate and enhance the ability of manufacturing industry to capitalise on the emergence of a powerful global information infrastructure. In this paper we suggest to combine the areas of media streaming services and manufacturing processes, by providing electronic learning offerings as collections of media streaming services. The key components of our approach are 1) an xml based streaming service specification language, 2) automated configuration of distributed E-Learning streaming applications, 3) web services for searching, registration, and creation of E-Learning streaming services.

***Keywords*— just-in-time learning; media streaming services; web services; manufacturing processes**

I. Introduction

Manufacturing processes involve the control and management of manufacturing systems ranging from basic assembly processes to the high-tech manufacture of pharmaceutical, telecommunications and electronic equipment. Categories for such manufacturing processes are assembly line / flow shop, and cellular manufacturing / group technology. E.g., in case of assembly line based processes a line of dissimilar machines are grouped in the line (sometimes more than one to balance flow). Innovation, productivity, flexibility, and continuous improvement are key ingredients to success in the constantly evolving world of manufacturing.

A major challenge to which companies must respond is the integration of advanced E-Learning technologies. What is actually needed is a learning "on demand", embedded into work processes, responding to both requirements from the work situation and from employee interests, a form of learning crossing boundaries of e-learning and performance support.

The goal of E-Learning services integration in manufacturing processes is, through the development of new IT solutions, to accelerate and enhance the ability of manufacturing industry to capitalise on the emergence of a powerful global information infrastructure.

Multimedia networking services support monitoring, controlling and supervising production processes in order to achieve high levels of efficiency and environmentally friendly production. The new flexibility of workers and work environments makes traditional conceptions of training in advance, in rather large units and separate from work activities, more and more obsolete. Manufacturing scenarios where E-Learning services can be integrated are shown in Fig. 1.

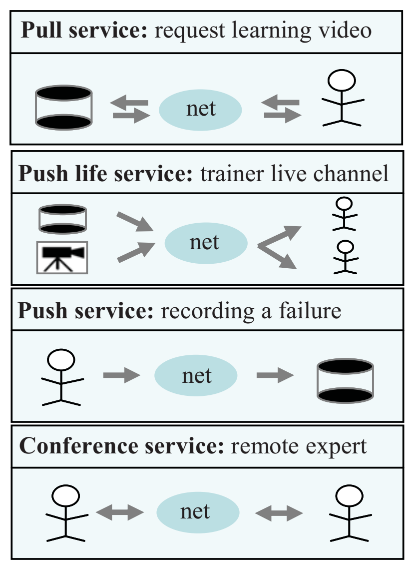

Figure 1. E-Learning services in manufacturing processes

The following streaming services can be identified:

- Pull (on demand) service: allows on demand access to remote E-Learning content, e.g. video content illustrating configuration of a CNC machine.

- Push service: e.g. a push channel from a remote expert to the manufacturing personal (“how to configure / operate a machine”). Live audio and video (expert) as well as media files can be delivered (see Fig. 1).
- Push service: for recording a failure scenario during a manufacturing process by recording the comments (voice) of a worker and by recording the machine status by video. This documentation can be used later to analyse details.
- Conference service for maintenance and remote diagnosis: teleoperation and remote diagnosis and maintenance of distant plant and production equipment can be achieved by using peer to peer E-Learning streaming services.

The remainder of this document is as follows. Section II makes a comparative digest into related work in this field of interest. In Section III we discuss a xml based language which allows specification of E-Learning streaming services while section IV outlines the architecture and describes the major components and technologies to solve the problems stated in section I. Finally, section V gives a brief summary and concludes with a note on future work.

II. RELATED WORK

[1] presents a framework for an on-demand E-learning management system that make use of broadband network for the delivery of distributed "educational activities" such as distributed courses, tutoring sessions, lectures, workshops, etc. The developped scheme is tailored towards personalized learning using distributed information in a dynamic and heterogeneous learning setting, i.e. a connected network of learning management entities and educational systems where learners are individually supported in accessing distributed resources. However it is restricted to on demand scenarios and multimedia files.

[2] introduces a framework for design and development of an interactive multimedia E-learning system for engineering training. The main goal of the project is to encourage low cost developing of effective and customized e-learning systems for engineering training by using popular and inexpensive software tools especially for **virtual simulation of engineering system operations.**

The Venice [3] project proposes a web services based framework for VoIP applications. By using a service oriented architecture, the authors aim at easing the integration of supplementary services, the compatibility between different signaling layer protocols for call control and the installation of software updates on client devices. However, the Venice project is specifically tailored to VoIP scenarios, i.e., the authors do not address reusability between different multimedia applications nor provide a generic platform for the development of these.

Based on a distributed messaging middleware, the Global Multimedia Collaboration System (Global MMCS) [4][5] provides a framework for an audio/video collaboration system, which bridges the gaps between nowadays multimedia applications by providing a common signaling protocol with gateways to existing protocols like SIP or H.323 [9]. However, the authors do not address other multimedia applications and the reuse of components between these.

In [11] a mobile streaming media CDN (Content Delivery Network) architecture is presented in which content segmentation, request routing, prefetch scheduling, and session handoff are controlled by SMIL [12] (Synchronized Multimedia Integrated Language) modification. The approach concentrates on the segmentation aspect, which is important for mobile users. In [13] also an XML based specification technique for streaming services is introduced. However, it does not enable the specification of quality of service attributes and distribution policies.

In [6] an approach is suggested to combine the areas of e-learning and Web services, by providing electronic learning offerings as (individual or collections of) Web services as well. It elaborates on this by showing how content providers and content consumers (i.e., learners) can communicate appropriately through a Web service platform with its common description, publication, and retrieval functionalities. However, it does not support live channels.

The JSR 309 [16] is designed to provide server-based Java applications with multimedia capabilities. It targets a large range of applications from simple ring-back tone applications to complex conferencing applications, by providing: media network connectivity to establish media streams, IVR functions to play/record/control multimedia contents from file or streaming server, ways to join/mix IVR function to network connection to create, conferences and call bridges. However the proposed API approach is restricted to Java based applications and it does not support enhanced VoIP functions, e.g ring groups or call queues. It mainly provides low level objects like players, recorders, mixers and connections that developers can manipulate or combine together to obtain all the multimedia capabilities.

[17] presents a generic framework for multimedia applications consisting of a set of reusable Web service components, a modeling language based on finite state automata and a compiler. The authors concentrate on the signaling plane protocols, especially their similar structure and purpose, i.e. the definition of possible states for both, client and server, and the transitions between these states via the exchange of messages.

[10] describes a service-oriented communication (SOC) paradigm based on Web services for real-time communication and converged communication services over IP. This approach extends Web services from a methodology for service integration to a framework for SOC. In particular, it introduces the generic Web services-based application session management (WS-session), the two-way full duplex Web services interaction for communication, and the development of Web Services Initiation Protocol.

III. SPECIFICATION OF E-LEARNING SERVICES

A. Model

Manufacturing processes are composed of manufacturing resources, e.g. manufacturing automation devices, equipment & machinery, material & manufactured parts, and manufacturing personnel. E-Learning streaming services are related to such manufacturing processes and / or single manufacturing resources. E.g. for a single machine a video on demand can be requested by the manufacturing personal to study the detailed configuration steps for such a machine.

The class diagram in Fig. 2 represents a model of our E-Learning streaming services (UML class diagram). Different fundamental components of the system are shown in the form of classes and relationships.

An E-Learning service can be described by its media objects, related manufacturing resource, distribution and replication policy, and the quality of service used for content delivery. Media streams can also be categorized according to how the media objects are delivered. In pull services data delivery is initiated and controlled from a client whereas in push services a server initiates data transfer and controls the flow. Conference services support scheduled and ad-hoc conferences. Such conferences contain the following attributes: date and time when the conference will take place, the invited participants and as an optional part the leader, the agenda as well as conference documents.

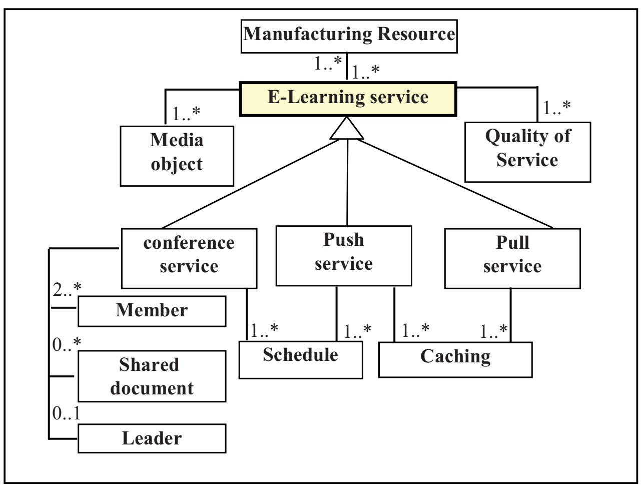

Figure 2. E-learning service model

B. Use Case: Life training

The following scenario (Fig. 3) illustrates one of our implemented use cases, a technical training (how to configure and operate a machine) for a computerized numerical control machine (CNC) as the related manufacturing resource: The operator shows the handling of a machine to the distributed audience. A background speaker (in a separate location, e.g. office) explains the configuration steps. To enable the interaction between the speaker and the learning community, each participant is offered an audio back channel. In the scenario there are different QoS requirements, e.g. for the video transmission showing the manufacturing machine a high resolution and frame rate is required.

The specification of media objects is based on SMIL [12]. SMIL (Synchronized Multimedia Integration Language) is an XML-based language, which facilitates the construction of accessible multimedia applications for the internet and mobile devices. Collections of XML elements and attributes can be used to describe the temporal and spatial coordination of one or more media objects.

In addition to SMIL, the type of media objects (live / file), the delivery policy and the roles which consume and supply media objects can be specified.

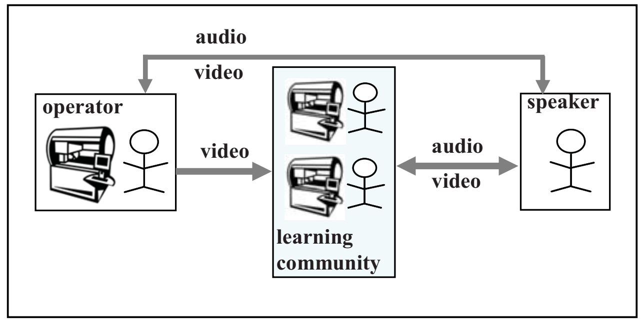

Figure 3. Example scenario

C. XML Specification

A specification of an E-Learning service is a structured composition of autonomous objects (see Fig. 4):

- resources or manufacturing processes (category, type, keywords)
- a collection of media objects, e.g. audio and video objects (life or files)
- distribution policy, e.g. push or pull
- roles and related media objects, e.g. speaker

This information can be used later, e.g. by the manufacturing personal, for searching and accessing E-Learning services.

Fig. 4 illustrates the specification of the life training scenario introduced in subsection A. The first part contains the description of manufacturing resources related to the E-Learning service. The list of media objects which are used in the service is part of the section "MediaObjects" together with the type, bitrate and source. The media streams are delivered based on a push policy. This includes also the definition when the media objects must be delivered (date and time), together with the available bit rates. Finally the roles, e.g. a speaker role or a operator role are introduced together with a list of media streams which are consumed and supplied by each role. E.g. the speaker consumes and supplies video as well as audio objects referenced in the section MediaObjects.

```
<StreamingService>
<ManufacturingResources>
   <resource  category = "num control machine" />
   <keywords>live training </keywords>
</ManufacturingResources>

<MediaObjects>
  <video id = "v1" type = "live"
                bitrate= … src =  … />
  <audio id = "a1 type = live"  src = …/>
  . . .
</MediaObjects>

<DistributionPolicy>
  <push codec="MPEG4" date= …  time=…
        recording="yes"
  </push>
</DistributionPolicy>
<Roles>
   <role name="Speaker"/>
     <consumerOf>
        <video id=… />
        <audio id=… />
   </role>
   . . .
</Roles>
. . .
```

Figure 4. E-Learning service specification

IV. SERVICE ORIENTED ARCHITECTURE

A service-oriented architecture (SOA) is basically a set of services interacting with each other and coordinating some activity. Service providers and service consumers are the two main entities acting on behalf of a user. The Web service technology additionally addresses a standardized description of a service's functionality using an XML dialect [14]. Using the Web Service Description Language (WSDL) [7], a service provider describes the functionality (interface) of a service in a platform, language, and operation system neutral way while a service requestor talks to these services using SOAP over HTTP (or other transport protocols).

A. E-Learning Streaming Services

Streaming services are managed by a set of web services (see Fig. 5). Such a web service is a URL-addressable software resource that performs operations and provides answers. In our case, the operations offered by the service interface are:

- searchStreamingService: allows searching a streaming service (based on the elements and attributes which form the xml service specification (e.g. category of a manufacturing resouce, type of media object, distribution policy, etc.).
- registerStreamingService: enables validation and registration of new streaming services.
- createStreamingService: instantiates streaming software components and establishes interconnections between components.
- startStreamingService: the operation start is typically invoked by a scheduler (in case of push based services, driven by date and time values).
- subscribeToStreamingService: allows users to subscribe to (future) streaming services (e.g. a remote video based training related to a certain CNC machine). When a new media streaming service is registered or started, a user will be notified automatically by the service manager (as soon as such a service has been registered to the xml database).

After searching a streaming service, the client (e.g. RTSP media player) sets up three network channels with the RTSP server when media data is delivered using the RTP over UDP, as shown in Fig. 5. A full-duplex TCP connection is used for control and negotiation. A simplex UDP channel is used for media data delivery using the RTP packet format. A full-duplex UDP channel called RTCP is used to provide synchronization information to the client and packet loss information to the server. RTSP initiates and controls delivery. The XML service description includes references to media streams, using the URL method rtsp.

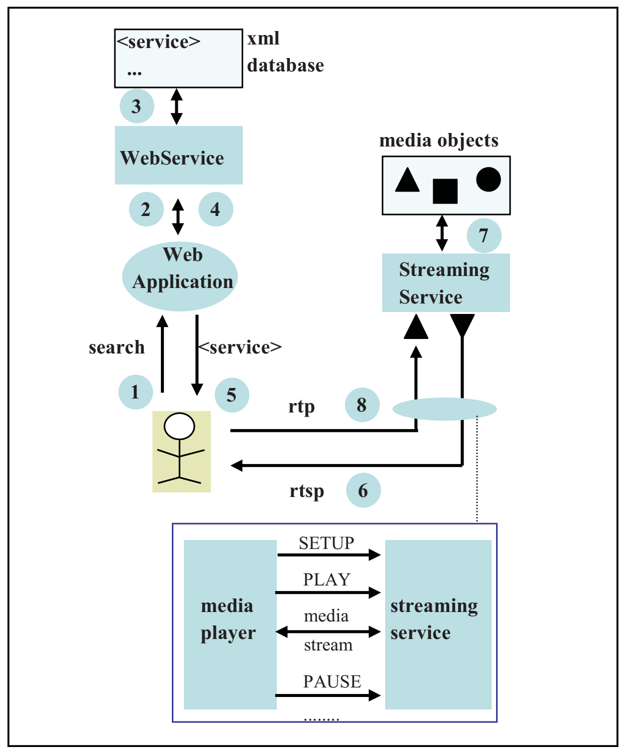

Figure 5. E-Learning Web services

According to our service specification language, the following properties of E-Learning services can be used as part of a query:

- manufacturing resources, e.g. category or keywords
- media objects properties, e.g. recorded live training
- distribution policy, e.g. on demand service

- QoS properties, e.g. bitrate, used codec
- Date / time duration attributes

B. *Prototype*

Our approach is based on a clear separation of a streaming service specification - and its implementation by a distributed application and can be used for different streaming paradigms, e.g. push and pull services.

The following figure (Fig. 6) illustrates the user interface and the management interface. The services are managed by a service manager, which provides in the current implementation a simple interface to search, and start (request) services. Moreover, a management interface enables creation of new services, and deletion of existing services. Service specifications are stored as XML documents in a XML database.

A new e-Learning streaming service specification is first analyzed by a web service (operation create) . Driven by a component library which contains existing streaming components, such as encoders, media servers, etc., and a set of configuration rules, a web service creates a distributed streaming application configuration. Based on such a service specification, the service manager also supports retrieval of existing services.

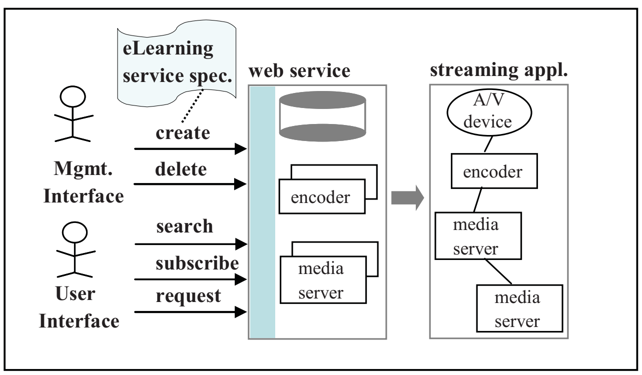

Figure 6. User interface and management interface

Push services are started automatically according to the specified date and time values. Starting a service means to create the required streaming components, e.g. an encoder and a media server component as well as to establish the communication relationships. Before a new service is created, a consistency checker is responsible to test the availability of nodes, and media objects according to the definition as part of a service specification. A service specification is then analyzed by a web service, which will select appropriate streaming software components.

Multimedia services are stored as XML documents in a XML database. We use Apache's Xindice, which is a database designed from the ground up to store XML data or what is more commonly referred to as a native XML database. Advantages are: faster for XML than other databases, no mapping to relational required, quick fragment retrieval provided, and optimized XML querying supported.

The prototype has been implemented using the PHP programming language and the PHP Web Services Development Pack nusoap [8] for the creation of and access to web services. We use the existing media server components from RealNetworks, and the OSS software Asterisk [15] as a VoIP server. The first (subjective) test results based on implementation of push and pull services as well as conference management are very promising. However, the used OSS VoIP system Asterisk does not offer scheduled conferences, i.e. a direct mapping to the Asterisk conference management functions is not possible. Information related to scheduled conferences are stored in a xml database. As the prototype is still under development, an objective measurement of processing time and delay has not yet been made.

C. *User Experience*

In a production environment robust and easy to use search functions are one of the key requirements. Our original search functions had to be improved. Context-driven search results, driven by the concrete manufacturing resources which are part of a single work place are regarded to be important for the machine operators. E.g. depending on the available machine(s) which are part of a single work place, the search functions have to offer the "right" E-Learning services related to the given local manufacturing resources.

The most accepted E-Learning streaming services are on demand video services. From the production management point of view, push services are essential for quality improvements. Such services allow a "just in time" documentation of occurred failures, during runtime of a machine by ad hoc video and audio recordings. These recordings can be analyzed later and appropriate solutions can be developed to improve manufacturing processes.

V. Conclusion and Future Work

In this paper we have presented a service oriented architecture for E-Learning streaming services – realized using web services technology. The major contributions and extensions of our approach aim to provide a high level specification of E-Learning services in terms of user roles, media objects, distribution policies, etc.. Based on such a service specification, a web service supports automated creation of tailor made media streaming applications, based on existing software components, e.g. media server or VoIP software components.

We report the current status of our prototype. The prototype has shown that our XML based language is well suited for automatic generation of implementations. At implementation level, the different aspects are integrated in a general object-oriented architecture supporting modularity and reuse of software. The deployment of new service operations is very easy to accomplish due to the modular structure of the service oriented architecture and the well designed and easy to use PHP development pack nusoap.

We do not use JMF [18], because it is not stable enough, especially for long running streaming applications. Instead, we use existing media streaming components (e.g. media server from RealNetworks).

Future work will concentrate on the extension of the service model to support additional functionality, e.g. application sharing. Another important aspect will be the integration of authentication services (authentication of users).

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Influence of PBL Practical Classes on Microcontroller-Based Digital Systems Learning

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***Abstract*— when practical classes are not properly planned and organized, students tend to see them as a mere requirement in which they should spend the minimum amount of time and effort. As a consequence, the aim of these practical classes is completely distorted. A solution to this problem is the well-known project based learning approach (PBL). In this paper, the influence of practical classes, each one organized as a small PBL activity, is analyzed in the field of a microcontroller-based system design course. When the results obtained in different years are compared in order to analyze an educational methodology, some variables of this analysis change (e.g.: the group of student, the difficulty of the exams, etc). Instead, in this paper the marks obtained by students that faced the practical classes correctly are compared with the marks of the students that considered them just as a requirement that needs to be fulfilled. In this way, the analysis is not distorted by the change of some variables.**

Keywords- PBL, microcontroller, digital, practical

I. INTRODUCTION

The Bologna process has highlighted the overly theoretical aspect of some courses in Spanish technical degrees [1, 2]. Also, when practical classes are not properly planned and organized, students tend to see them as a mere requirement in which they should spend the minimum amount of time and effort. As a consequence, they lose the opportunity to put into practice what they are taught in lectures. Hence, they tend to acquire this new knowledge in an excessively theoretical way, without promoting the skill at applying it to the real situations they will face once they graduate. Another consequence of these wrong-planned practical classes is that skills such as collaborative work, task management, critical thinking, etc. are not properly promoted.

The project-Based Learning (PBL) is a useful approach in order to eliminate this two negative consequences [3-5]. Not only students are given the opportunity to put into practice what they learn in lecture classes, but also they work in an environment in which collaborative work and other important skills are needed (public presentations, etc.). As a consequence, the knowledge acquired in lectures is not simply memorized; it becomes a tool for solving the problems that students will face in their future jobs. This is even more evident in courses in which, due to their thematic, students have the opportunity to use real equipment in the practical classes [6-8]. This is only possible when there are enough workbenches, which usually implies low-cost equipment, and also when some autonomy can be given to students, which usually implies that there is no risk for equipment or students if they work without direct lecturer's supervision.

In this paper, the influence of PBL on a microcontroller-based-system design course is analyzed. The main objective is determining how the learning process of students is affected depending on the way they face PBL-based practical classes. Without any change in the lecture classes, each practical class is organized as a small PBL activity: alarm with hysteretic levels for controlling an analog measurement, chronometer controlled by matrix keyboard, thermometer with temperature record, etc. One of the key issues of this paper is the way in which the results are analyzed. Instead of comparing the results obtained this year with the results obtained in previous ones, in which the practical classes were not PBL-oriented, the analysis compares the results obtained by students that tried to benefit from practical classes with the results obtained by students that considered them as a requirement. In this way, there is no variation of certain variables in the analysis, such as the group of student, the difficulty of exams or the group of lecturers.

The organization of this paper is as follows: firstly, a brief description of the course is given in order to have a complete framework (section II). In section III, the new practical classes approach, based on PBL, are described. The way in which the dedication to practical classes is measured is described in section IV. In this section, the analysis of the results is also presented. This is completed by the test results explained in section V. Finally, some conclusions will be presented (section VI).

II. COURSE DESCRIPTION

The PBL approach analyzed in this paper is applied to an annual course of telecommunication engineering degree. The course is centered in the design and development of microcontroller-based systems and is given in the third academic year. Evaluation is done by means of two exams. The first one is set at the end of the first semester and the second one is set at the end of the academic year. In these exams, only practical questions are done, trying to avoid contents memorization by students. In the final evaluation, the results obtained in practical classes are also taken into account (the evaluation of practical classes is explained in the next section).

The number of students is approximately one hundred, divided in two groups for lectures and five groups for practices. This means that the number of students per practical group is twenty. This high number of students has a very important influence on the way practical classes are organized, as it will be explained later.

Another important aspect related to practical classes is that the topic of the course implies, on one hand, low-cost equipment and, on the other, no risk for students when solving each project on their own [9, 10]. Hence, it is possible to have enough number of workbenches and to leave the laboratory open for the students without lecturer's direct supervision (see Fig. 1).

III. PRACTICAL CLASSES DESCRIPTION

Practical classes, as has been mentioned, are PBL oriented. The aim is that students do not simply memorize what is explained in lecture classes. Instead, they should acquire the skill of using it for solving the real-life problems they will face in their future jobs. Also, other skills demanded by companies in their new workers are promoted (e.g.: collaborative work, public presentation, etc.).

Firstly, it should be taken into account that the number of lecturers for the whole course is only two, what makes the number of students too high for a traditional PBL to be done. Hence, each practical class is organized as a small PBL activity rather than developing a larger one for the whole academic year. In this way, the supervision task is simplified and can be done by the reduced number of lecturers in charge of the course (see Table I). Nevertheless, the main reason that justifies this organization of the practical classes is another. Each of this small PBL activities is related to one (or two) of the topics of the course. In this way, students have the opportunity to put into practice what is explained in lecture classes, improving their skill of applying their new acquired knowledge to real problems, rather than simply memorizing it. To help this approach, a special effort is done in giving each practical class once the corresponding topics have been explained in lectures and once the students have had time to prepare and study them. In this way, the idea of practical class as a mere requirement tends to be blurred.

Figure 1. a) Laboratory with 12 workbenches for the practical classes; b) Workbench for every working group of 2-3 students; c) elements for debugging/testing the solution implemented for each project.

TABLE I. PROPOSED SMALL PROJECT FOR EACH PRACTICAL SESSION.

	Project description	Related Topics
1	First contact with the debugging/programming tool (MPLAB IDE, ICD2, etc.)	Microcontroller introduction
2	Counting the number of times a button is pressed. Representation of this number by means of four LEDs (in binary)	In/Out ports
3	Creation of different visual effects by means of four LEDs (changes from one effect to another are forced by pressing the button)	In/Out ports Software Timers
4	Chronometer with run/stop and reset buttons. Time represented with three seven-segment displays.	Hardware Timers Seven-segment displays
5	Chronometer controlled by means of a matrix keyboard of 16 keys.	Hardware Timers Interruptions Matrix keyboards
6	Digital Frecuencymeter (range: 10-20000 Hz)	CCP module (Capture) Interruptions
7	Chronometer controlled by means of a matrix keyboard and with a LCD display	LCD display CCP module (Comparison) Matrix keyboards
8	Alarm with hysteresis for controlling an analog voltage value which needs to be shown every second on the LCD display.	CCP module (PWM and comparison) AD converter
9	Data-logger of the information sent by the PC (serial communication)	USART module (asynchronous communication)
10	Temperature measurement (sensor controlled by I2C) and storation of the results in an external memory. The stored data will be sent to a PC when demanded (serial communication)	SSP module (I2C) USART module External devices (temperature sensor, EEPROM memory,…)

In order to promote the acquisition of certain skills such as team work and task management, students were organized in working groups of two or three members (hence, in each practical class there are seven or eight working groups). In principle, a higher number of students per group would increase the development of these skills. Nevertheless, it should be taken into account that one of the key issues for PBL success is avoiding passive member in each group. Considering that each practical class is organized as a small PBL activity, a higher number of students per working group would lead to a reduced amount of work per student and would favor the passive attitude of some of the members.

Evaluation of each activity is also planned so that students acquire and develop certain skill like, for instance, oral expression, public presentation or technical writing. When a working group has finished one of the proposed projects, its members explain their solution to lecturers, justifying the design decisions they made. Also, they have to answer the questions asked by lecturers, who act as contractors of the working group. Besides, a report has to be handed over by every student. In this practical report they have to explain their solution and answer to a questionnaire with practical and theoretical questions related to the corresponding topic (but not necessarily to the project proposed for that topic). In this way, students need to study what has been explained in lectures in order to do the practical report. Hence, not only the mentioned skills are promoted, but also copying is prevented or, at least, is easily detected and the appropriate measures can be taken [11].

An important aspect that should be highlighted, and that later will be discussed as a possible improvement of the proposed approach, is the absence of a limit date for handing over each project solution. Nevertheless, it was strongly emphasized by lecturers that practical classes would only be useful if each project is done immediately after the related topics are explained in lectures and before the next topics are finished. This leads to a two-week period of time for doing and finishing each project. The aim was improving the self-management of each student and of each working group.

IV. Analysis of the Proposed Methodology

The effectiveness of the proposed method is going to be analyzed comparing the results obtained by students of the same academic year. In this way, the influence of certain variables that change from one year to another (students, exam and lecturers) is neglected. Specifically, in this analysis the results obtained by students who respected the proposed date of handing over are compared with the results obtained by students who did not. That is, a relation between the results obtained in the course (final mark) and the dedication degree to practical classes is established.

A good measure of the dedication degree to practical classes (rather than the mark obtained in their evaluation) is the date of handing over. In this way, students that try to benefit from practical classes have earlier dates if compared with students that only try to 'fulfill the requirement'. Obviously, it is possible to consider that the opposite situation may happen: students that do not see the proposed projects as an opportunity to improve their knowledge have earlier dates of handing over as they try to finish as soon as possible. It should be taken into account that each practical class needs a previous studying of the concepts explained in lecture classes (something characteristic of PBL). As a consequence, the students who try to observe the recommendations of the lecturers usually have the earliest handing over dates. Also, these students have the higher marks in the practical evaluation (nevertheless, this variable is not considered for measuring the dedication degree).

Considering this, the handing over date of each student was taken down in order to measure the dedication degree. In this way, it is possible to calculate an average handing over date for each practical session at the end of the academic year:

$$HOD_i = \frac{\sum_{X=1}^{N} HOD_{X\_i}}{N} \quad (1)$$

in which HOD_i is the average handing over date of project number i, HOD_{X_i} is the handing over date of student X for project number i and N is the overall number of students.

With this average value, it is possible to determine the dedication degree of each student to each practical class (DD_{X_i}) by means of the following equation:

$$DD_{X\_i} = HOD_i - HOD_{X\_i} \quad (2)$$

in which positive values means that the student presented the solution before the average date and negative values after the average date. That is, positive values means high dedication degree and negative values means low dedication degree. Calculating the average value of the ten practical sessions for each student, it is possible to obtain a numerical value that measures the dedication to practical classes:

$$DD_X = \frac{\sum_{i=1}^{10} DD_{X\_i}}{10} \quad (3)$$

in which DD_X represents the dedication degree of student x considering that the total number of practical classes is ten.

The other variable analyzed is the mark obtained in the course. In this mark, it is taken into account not only the results in the two exams, but also the evaluation of the practical classes. In this way, the final mark represents the success not only in knowledge acquisition (mainly evaluated by means of the two exams), but also in skill acquisition (mainly evaluated by means of practical classes).

In Fig. 2, the relationship between the two variables is shown. The x-axis represents the dedication degree, in which positive values represent a high degree of dedication whereas the negative values represent low ones. This variable has been normalized to the maximum positive value. The y-axis represents the mark obtained in the course. The pass is

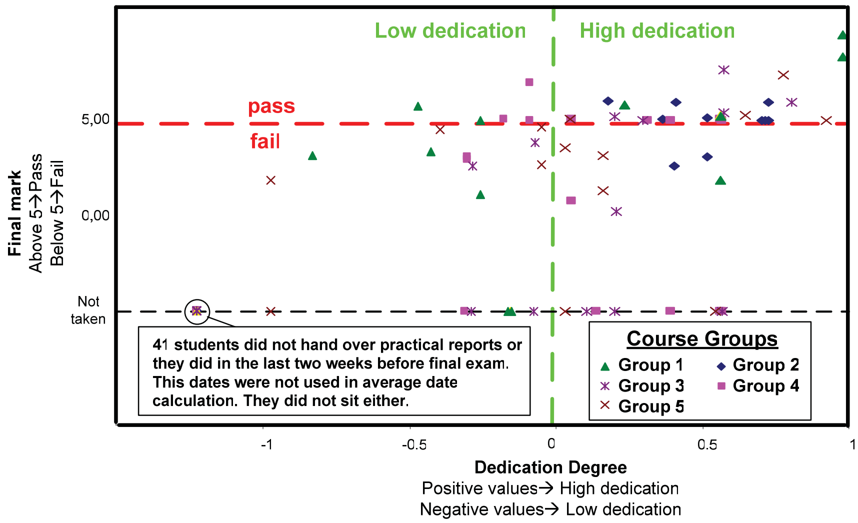

Figure 2. Comparison between dedication degree and the final mark of each student. The five practical groups (or course groups) are differentiated.

achieved with a minimum mark of five and the maximum mark is ten.

The first important result that should be highlighted is that the number of students that did not sit the exam is considerably lower in the group with a higher degree of dedication. Specifically, 9 students with a positive degree of dedication did not sit the exam, whereas in the negative-dedication group this number rises to 47. This means that only 16% of the students that did no take the exam had a positive degree of dedication. This result is even better if it is taken into account that some of those nine students were closed to a passive attitude in their working group, taking advantage of their mates but without being clearly detected during the presentation of each small project. This is something that should be corrected with the improvements proposed later.

The analysis of the results obtained by students that took the exam also validates the proposed methodology. The best marks are obtained by students with the highest degrees of dedication. In fact, in this group the number of students with a mark above five is 26, whereas the number of fails in this group is only 9. This means that 75% of the students that faced practical classes in a correct way passed the exam. On the other hand, only 5 students with a negative degree of dedication passed the exam, which is a low number if compared with the 12 students that failed. This means that only 29% of the students that did not take into account the proposed handing over date passed the exam.

It should be noted that 41 did not hand over all the practical reports or they did in the last two weeks before the exam. Their handing over date was not taken into account for determining the HOD_i. If these dates had been considered, the analysis would have been distorted as these students did not even assist to lectures. That is, they gave up the course before the first semester ended. This fact will be deeply discussed in the next section, as it has a very close relation to the absence of a mandatory handing over date.

V. ANALYSIS OF THE TEST RESULTS

At this point, it is only possible to ensure that a relation between high degree of dedication and satisfactory knowledge and skill acquisition exists. Nevertheless, it is not possible to ensure that these good results are a consequence of the proposed method. It is possible to consider that good student would have obtained higher marks independently from the approach employed in practical classes. In order to clarify this point, at the end of the academic year a test with several questions about the proposed method was done by every student. The results obtained for each question are shown in Fig. 3, in which a value of ten means *'I totally agree'* and a value of zero means *'I totally disagree'*.

The first two questions of the test were:

- Question 1: The practical classes helped me in understanding the theoretical contents of the course.
- Question 2: Complementing every topic with a practical class helped me in understanding what is explained in lecture classes.

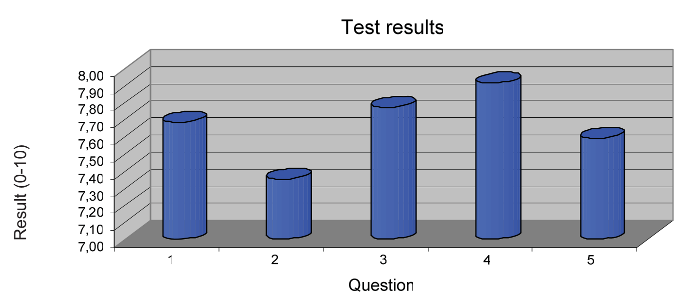

Figure 3. Results of the test done by every student.

As can be seen, the results show that the proposed methodology, in which each practical session is organized as a small project, helps students in acquiring the knowledge as a useful tool, rather than simply memorizing it. This is the main objective and it has been fulfilled.

Other objective was the improvement of certain skills such as collaborative work or public presentation, strongly demanded for new engineers in their jobs. This aspect was analyzed by means of the following question:

- Question 3: The practical classes allowed me to practice certain skills such as collaborative work.

The result shows that this point was also covered by the proposed methodology.

Finally, the last two questions asked in the test were:

- Question 4: Practical classes have shown me that a real project is more complex than solving a problem 'on the paper'.
- Question 5: Practical classes have shown me that a real project involves numerous related topics (analog electronics, common sense, etc.)

The objective of showing the students that the new knowledge is not only theoretical contents that have to be memorized is also fulfilled (these two questions have close relation to the first two).

If all the results are considered (not only the test results, but also the comparison between dedication degree and final mark), it is possible to infer that the proposed methodology satisfies all the goals pursued by lecturers. The knowledge is not simply memorized; it is acquired by students as a tool for solving the real problem they will face in their future jobs. Also, other very important skills (oral expression, critical thinking and technical writing) are also promoted by this methodology. The main drawback for PBL to be implemented in this course was the high ratio students-lecturers. Nevertheless, the results show that this problem can be avoided if small PBL activities are planned all along the course duration instead of a single and more complex project.

There are some aspects that can be improved. The handing over limit date was only a recommendation. As a consequence, only 44 students had positive dedication degrees. Also, 41 students did not sit the exam. Considering that the method has proven to be effective, the suggested handing over date should be turned into a mandatory date, as a trial for decreasing the number of students giving up the course. This involves some difficulties. The most important one is: What happens if a student does not present a project solution before that date? The easiest option would be that student failing the whole course. Nevertheless, this would not necessarily increase the number of students with positive dedication degree. Possibly, this would increment the number of students copying from classmates or, even worse, incrementing the number of fails just due to a delay of a few days. This is a typical problem of PBL and there is not any easy solution: bonuses in the final mark for those students that presented all practices on time, reducing the mark obtained in a practice for every day of delay, etc. All possible solutions have merits and flaws. Lecturers should select the one which better suits the course, the PBL activity and the theme of the course.

Another remarkably aspect that should be highlighted is that the PBL approach demands more dedication not only from students, but also from lecturers, whose availability for the students can not be limited to the practical classes timetable. Students work in the proposed projects all along the two weeks between each practical class. Sometimes, they get stuck and need some help in order not to lose excessive time. This does not mean that every problem needs to be solved by lecturers in the instant that it appears (students have to deal with difficulties trying to find the solution on their own or the PBL loses its benefits). Nevertheless, if they have tried several possible solutions and they did not work, students should have the possibility of asking for "immediate" lecturer's help in order not to lose excessive time and fall behind. As a possible solution, the two lecturers in charge of practical classes organized themselves so that there was always one of them available for students during teaching hours (not in the practice's laboratory, but in their office or research laboratory). Nevertheless, the best option for this proposed methodology would be incrementing the number of lecturers from two to three or four, something that does not depend on them but on the University organization.

VI. Conclusions

In this paper, evaluation of a PBL approach applied to a microcontroller-based system design course has been analyzed. Due to the reduced number of lecturers in charge of practical classes, the PBL methodology was applied by means of small projects rather than a more complex single project. The analysis of the results tries to eliminate the influence of certain variables (group of students, difficulty of the final exam or group of lecturers) that may change if the analysis is done comparing the results obtained in different years, in which some of them the old methodology was used and, in the rest, the new one. These results show that the proposed methodology helps student in acquiring the new knowledge not as theoretical concepts that have to be memorized, but as a tool for solving real problems. The efficiency of PBL is already perfectly known, but the proposed PBL-based methodology is an option to be considered when the number of lecturers available is low for a typical PBL.

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TICTAC

Information and Communication Technologies for Augmentative Communication Boards

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Abstract— **Providing a communication aid is a complex issue which requires a deep insight on the theoretical backgrounds, the technological basis and, specially, the problems faced in bringing together the expectations and needs of users, teachers, speech therapists, families... and the perspectives and knowledge of linguists, teachers, engineers and speech pathologists. In this on-going project we intend to develop and implement helpful tools for students with communicative impairment by means of communication boards based on icons, pictures or conventional characters.**

Keywords-Augmentative and Alternative Communication, Communication Boards, Special Needs, Accessibility

I. INTRODUCTION

The development of a human being depends a great deal on the ability to communicate. Not only social aspects are involved, but also those related to psychological stability and cognitive development.

History is full of examples of great people who made their way through communication difficulties. Hellen Keller, deaf-blind was the first person gaining a Bachelor Degree of Arts, a great author. Political activist and lecturer, she would have been lost without Anne Sullivan's determination.

In 1995 Jean-Dominique Bauby, editor-in-chief of French Elle magazine suffered a rare kind of stroke who left him in a locked-in syndrome (a condition in which a perfectly agile mind is trapped in a useless body). He could not walk, eat or even breath. All he could do was blinking his left eye. He dictated an entire book on his experiences by having the alphabet told and blinking to select a letter. His story inspired the film *Le Scaphandre et le papillon* (The Diving Bell and the Butterfly).

It is also inevitable to mention Stephen Hawking, whose colossal efforts allow us to enjoy the ideas and theories of one of the most influential physicist nowadays.

This colossal efforts are made at an outstanding personal cost, and here is where technological aids may provide that extra-help needed to forget about communication methods and to focus on communicative content.

Digital aids have proven helpful in getting the message from those unable to speak or even write through conventional methods. If we do not help every student to effectively communicate and develop their minds to the maximum we would never know how many great minds are we leaving behind, locked in dysfunctional bodies.

Readiness as a key aspect in a communicative act. It is important, not only to provide with an effective way of communication, but it also has to be a quick one. This way we allow the user to keep pace of a conversation. Otherwise the hole speech would result in a monologue.

Personal assistants dictating the alphabet have been replace by scanning switch activated keyboards. The former went through all the available characters following, in most cases, the conventional alphabetic order. As for the latter, the standard is the QWERTY display. None of the sequences has been set with a scanning approach in mind.

This project is aimed to explore and optimize the scanning sequence implementing a frequency based sequence (recently used by communication assistants), thus reducing time waste and allowing more fluent communicative exchanges.

We will set the basis of augmentative and alternative communication to analyze conventional communication boards used with students and adults. The TICTAC approach will be presented to have a better idea of the whole communication strategy behind the project. Finally we will go through the main features of TICTAC virtual keyboard.

As it is a work in process final results are yet to come, but there are indicators showing a lot of people may find this keyboard useful, making a difference in their everyday lifes.

II. AUGMENTATIVE AND ALTERNATIVE COMMUNICATION

A. Defining AAC Systems

According to the American Speech-Language-Hearing Association (ASHA):

Augmentative and alternative communication (AAC) includes all forms of communication (other than oral speech) that are used to express thoughts, needs, wants, and ideas. We all use AAC when we make facial expressions or gestures, use symbols or pictures, or write.

People with severe speech or language problems rely on AAC to supplement existing speech or replace speech that is not functional. Special augmentative aids, such as picture and symbol communication boards and electronic devices, are available to help people express themselves. This may increase social interaction, school performance, and feelings of self-worth [1].

There are many types of AAC but they tend to fall into two main groups:

- Unaided communication systems, such as gestures, sign language or traditional communication boards. They do not provide voice output and no electronic hardware is involved.
- Aided communication systems which are the trend nowadays:

[...]electronic devices that may or may not provide some type of voice output. Devices that provide voice output are called speech generating devices. These devices can display letters, words, and phrases, or a variety of symbols, to allow the user to construct messages. Messages can be spoken electronically and/or printed on a visual display or strip of paper. Many of them can connect to a computer for written communication. Some of them can be programmed to output different spoken languages [1].

B. AAC User

The first difficulty we come across with when we try to identify the potential user is the lack of patterns in this population. They come from all age and socio-economic groups; appear in all backgrounds, have all sort of health conditions and show different levels of communication performance.

The ASHA gave us the most commonly used definition of this population.

Individual with severe communication disorders are those who may benefit from AAC -those for whom gestural, speech, and/or written communication is temporarily or permanently inadequate to meet all of their communication needs. For those individuals, hearing impairment is not the primary cause for the communication impairment. Although some individuals may be able to produce a limited amount of speech, it is inadequate to meet their varied communication needs. Numerous terms that were initially used in the field but are rarely mentioned include speechless, nonoral, nonvocal, nonverbal, an aphonic [2].

A number of studies [3] suggest that 8 to 12 people per 1.000 may experience severe communication impairments that require AAC.

C. Ethiology

We must assume there is no typical AAC user, even given the same primary cause for the lack of communicative exchange.

Nevertheless disabling conditions that may require AAC have been categorized into four types [4]: congenital conditions, acquired disabilities, progressive neurological diseases and temporary conditions. Cerebral palsy, mental retardation or autism are examples of congenital conditions. Acquired impairments that may lead to the use of AAC include traumatic brain injury, cerebral vascular accident, laryngectomy or glossectomy. There is a number of progressive neurological diseases with an impact on communication such as multiple sclerosis or Parkinson's disease. Finally, we must consider those cases in which the restriction in communication is temporal (e.g. intubation or severe facial burns).

III. Communication Boards

A communication board is a technical help for AAC users consisting in a surface where the communication facilitator displays a variety of icons, symbols, letters, words... for the person to point, stare at, or select by any means available (such as automatic scrolling for scanning).

A. Traditional

These are hand-made custom boards. The facilitator decides on the concepts included and their display. Then, he places them on the board (a piece of wood, cardboard, plastic...) either manually or setting the display with the aid of a computer program such as Boardmaker [5] and printing the complete board to stick it to an appropriate surface.

These, though very popular both in primary and secondary school, highly limit the communicative competence of the individual and basically avoid any possibility of a conversation.

B. Electronic

We include here most commercial communicators. Some of them barely differ from the traditional ones except for the fact that the selection triggers an action (generation of artificial voice, playing an audio file or printing a message on the screen or paper). The level of customization varies considerably among them. Some may be designed from scratch while others are predetermined by default with little room for customization.

Their readiness and the supporting role of the company selling the product to solve eventual problems is to be taken into account.

But a careful *cost-benefit* study must be carried out from a long-term perspective as they are not so useful with this idea in mind. It also limits considerably the vocabulary available and the structure of the sentences, which becomes more and more important as the studies approach to a university level.

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C. Digital

Communication Boards based on digital environments are becoming less scarce. Although most commercial digital boards are simply unaffordable for most families or institutions; the efforts of professionals in bringing together their IT skills with their AAC mastery are laying the foundations of an exciting new way of approaching AAC.

People with severe impairment are especially vulnerable to separation from the mainstream society. Technologies applied to AAC systems may help to bridge that gap [6].

IV. Digital Communication Board

In order to help people (particularly students) showing communication impairments, we are currently working on a set of two digital communication boards aiming two radically different problems. Both of them draw the limits of the issue according to the "ability to write" criterion. This ability should be assessed in 'cognitive terms' rather than 'motility terms'.

An cognitively impaired person who is, as a result, unable to read or write needs a communication system capable of easily transmit basic needs and feelings. They do not feel the urge to communicate and just do as they please with a very low tolerance to frustration. They interact with a limited number of people (therapist, teachers, etc), normally trained *ad hoc* to understand their jargon. In other words we need to focus on simplicity in terms of access, meaning and use: a simple message followed by a quick response. Iconic communication serves this cause effectively.

On the other hand, physically impaired users preserve all the intelligence (average or gifted) and have the need to express themselves in complex ways. They have a better frustration handling and are able to deal with delayed responses. They are also able to enrich their message with a variety of paralinguistic resources. Their social network is wider and may benefit extremely from the use of written language.

A. AAC Systems Board

The first board has been completely developed as an icon/picture based board intended for AAC Systems in individuals without the ability to acquire a written code. A basic form of A.I. allows it to continually adapt itself to the needs of the user, as well as being proactively adapted by speech therapists and caretakers. It includes built-in functions to improve basic communication skills. It has also been partially implemented and tested by a pilot user.

This board has been already described [7] and will not be discussed here as it is highly improbable for one of its users to reach engineering studies (either vocational or university), given the cognitive impairment associated to the communicative problem. We can not rule it out completely, though as we are discovering interesting capabilities particularly in mathematics an physics in certain individuals, e.g. autistic savants may be unable to read or write but could understand and express complicated formulas and equations given in mathematical notation.

B. Virtual Keyboard

The second board is being developed and expected to be implemented and tested by pilot users by the second term of this academic year. It is intended for those physically impaired and thus, unable to hand-write or use an adapted keyboard but who are cognitively able to write. It consists of a virtual scanning keyboard optimized using cryptography algorithms activated through any standard or custom-made push-button.

This is, due to its characteristics and features, the communication board most likely to be used by engineering students with special needs, and unable to make use of conventional virtual keyboard; thus, demanding a scanning system to select the different characters and symbols.

Writing through a scanning device is somehow similar to playing scrabble, only here you have an specific message to deliver. Given this situation you would rather get an 'j' than a 'w' when writing in Spanish (or exactly the opposite in English). This approach sets the basis of the virtual keyboard.

Scanning programs like Kanghooru (http://www.xtec.cat/~jlagares/f2kesp.htm) allow setting the optimal computer screen scanning order for each individual case. This type of programs may be used in conjunction with TICTAC keyboard to operate a computer. Bearing this in mind, four 'keys' have been left blank (e.g. launching software).

The keyboard is also able to speak when used with Llegir (http://www.xtec.cat/~jlagares/f2kesp.htm), a text-to-speach program specifically designed for physically impaired users.

V. Virtual Keyboard analisys

A. Display

This board is set as a conventional virtual keyboard, displayed on screen and maximizing the character area to enable students with visual impairment or difficulties in staring at a particular point to go through the board with following the scanning.

There is a number of differences which outstand against the traditional QWERTY keyboard in terms of display:

- All conventional function keys have been removed.
- All symbols have been grouped under the symbol category.
- The upper line is used for the compacting categories: vowels, consonants, capital letter, number, symbol, control, end.
- Vowels come first, they are colored distinctively and ordered within their category according to frequency criterion, this is, the more used the vowel in the language selected, the earlier will be scanned.
- Consonants are the next category, also distinctively colored, and again ordered according to their frequency in the language selected.

- *May* turns the letter selected into a Capital Letter. There is no Capitals Lock.
- Numbers are ordered conventionally.
- All symbols available are displayed and have been reduced to the ones which are essential for communication. E.g. we only include closing question and exclamation marks, because those are the ones required in many languages, and enough in Spanish to give the intention implied in the message.
- The .com extension has been included as a facilitator given its importance and prevalence in on-line communications, and its difficulty to be written by scanning.
- b_t / b_p/ b_l are accessed through the control button and stand for delete_ everything /delete_word / delete_letter (borrar_todo, borrar_palabra, borrar_ letra, in spanish) respectively.

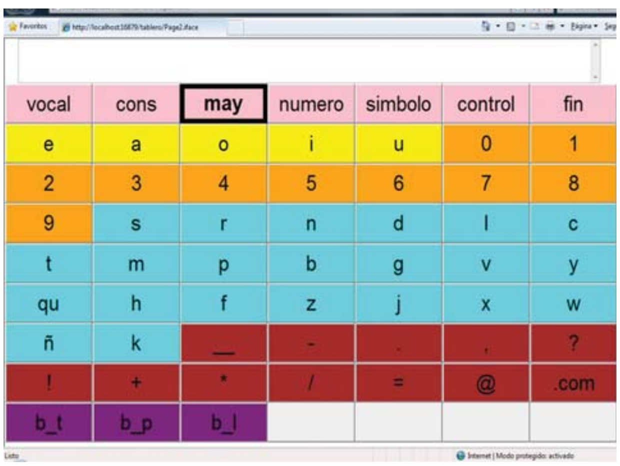

Figure 1. Keyboard display

B. *Letter frequency*

As we have mentioned earlier, all vowels and consonants have been arranged within the keyboard to follow their frequency order in the language used.

A lot has been discussed [8] on the QWERTY letter distribution but contrary to the urban legend (assuming the display slowed the typist), this was developed according to statistical evidence on letter frequency in English but intended to be use with both hands (ten fingers) at a time. This means it is a very fast display if you can use ten fingers moving over the keyboard. Scanning through a QWERTY keyboard distorts the benefits derived from a careful design. Much of the same applies to following the Latin alphabet on its conventional order.

There are two languages available in this keyboard: Spanish (Castilian) and Galician.

Letter frequency is available for Spanish [9], but it had not been determined for Galician. To confirm the information found for Spanish as well as to establish the letter frequency in Galician, a statistical analysis was run using *Make Character (Letter) Frequency Count Software* by Sobolsoft, based on long texts (above a million characters)

Nevertheless the frequency of the letters in a language depends a great deal on the type of text used (e.g. a legal text tends to the use of particular verb forms increasing the prevalence of 'r' or 'd' or 'n'. That is why, instead of using one single text, the letter frequency has been determined using different texts from a variety of sources. Further field tests need to be done to adjust the order of the letters to everyday use. As *practice makes perfect*, it is clear that once determined an order, the user should keep it as practice gained increases speed much more than any eventual modification to fit minor statistical differences.

C. *Technical Issues*

This virtual keyboard is a web application. It has been developed in Netbeans 6.5 and the application server will be Sun Glassfish v. 2. The programming language used is Sun Java EE5 with IceFaces framework. This framework applies Ajax (Asynchronous JavaScript + XML) transparently to the programmer. Using this technology we avoid flickers and reloading screens as well as making the program less bandwidth demanding and enhancing the user experience.

D. *Keyboard Access*

To select a character from the keyboard while it is been automatically scanned, the users must provide a click by any means available to their mobility. This could be pressing a push-button, blowing on a microphone or using any other click emulator.

To facilitate learning and adapting the keyboard to users expertise and mobility the scanning speed can be adjust to:

- Very slow: 10 seconds
- Slow: 8 seconds
- Normal: 5 seconds
- Fast: 3 seconds
- Very fast: 2 seconds

These categories have been determined through observation and practice and might be subject to revision.

Figure 2. Configuration Screen

ACKNOWLEDGMENT

We would like to recognize the work of Álvaro Novo Quiza, who made, a useful contribution to communication in severely physical impaired students, but otherwise as smart as a teacher could desire. They can now express themselves and show what they are capable of. Thank you for contributing with your End of Degree Project.

We would also like to thank the teachers and students in CEIP Seis do Nadal, particularly Ángeles, for been so welcoming and giving us an opportunity to try our virtual keyboard.

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Integrating digital video resources in teaching e-learning engineering courses

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***Abstract*—In recent years, the possibilities for distance teaching in engineering education have increased tremendously. The widespread availability of the Internet has allowed the use of rich media over long distances. As visual connectivity improves, an opportunity to enrich and rethink the place of learning design in on-line and distance education is presenting itself. This paper presents a case study of development of digital video to be used in e-learning postgraduate engineering courses. Videos should be used in autonomous DVD or embedded in hypermedia learning objects. Multilingual, interactive questionnaires and mixing use of animations and real images are some features of the video. The use of these video is put to the test in a postgraduate course on Solar Energy and other Renewable Energies in Buildings**

Keywords-component; Video teaching media, solar energy, engineering education.

I. Introduction

Some studies in the field of engineering education [1], [2] point out that one of the future trends will be the greater utilization of information and communication technologies (ICT) in ways that improve teaching and learning. It is expected that such ICT will increase accessibility of students to engineering programs and allow students greater flexibility in terms of how, when and where they study. These ICT would be used in undergraduate programs as well as in postgraduate programs and engineering lifelong learning, as long as this technology can be used to accomplish pedagogical goals. The only theoretical presumption is that educational outcomes would determine the selection of teaching delivery media. That means that the introduction of the ICT must be accompanied by improvements in the understanding of learning and teaching [3], [4]. Thus, the explosion of ICT has presented teachers with the opportunity of revisit the whole question of teaching and learning and to explore new forms of deliverables that supports students' creativity.

Besides electronic books and links to technical web sites, ICT aided engineering courses frequently involves multimedia presentation with interactive exercises and questionnaires, technical video and hypermedia tools, included to promote active learning.

This paper presents a case study of development of digital video to be used in e-learning postgraduate engineering courses. Videos should be used in autonomous DVD or embedded in hypermedia learning objects. Multilingual, interactive questionnaires and mixing use of animations and real images are some features of the video. The use of these video is put to the test in a postgraduate course on Solar Energy and other Renewable Energies in Buildings, within the framework of an international e-learning project. The pilot experience was designed to answer, amongst other, the question about what would be the students' usage during the course and what would be the implications of this experience for further developments.

II. Digital Video in Education

The applications and potential benefits of the use of video in teaching and learning started with the analogue videotapes in the early seventies [5, 6]. In some cases, video technology was used to improve practical teaching by developing simulated laboratory sessions [7]. In others, video-taped lectures were used in distance courses as a substitute of traditional lectures [8]. Nowadays, with the broad use of digital technology, video can be considered as a powerful medium that, first, can provide narrative visualization, and second, can engage multiple senses of learners simultaneously. Educational applications incorporating videotapes, digital video and on-line video can be found in disciplines as diverse as management, language teaching, physics and mathematical sciences, medical education and engineering.

Traditional forms of educational video include film, broadcast television and video cassette playback. Analogue video disks allowed video resources to be integrated into computer-based learning, but this technology was relatively expensive and did not become widespread. With the advent of digital video, video resources can be distributed to students via CD-ROM or DVD, on-line via the Internet, and embedded within other computer-based learning resources. Compared to traditional forms of video which are viewed primarily in a linear sequence, digital video permits more effective interactivity and control, as video elements can be quickly selected by the user, or controlled by a computer program, in any desired sequence. Although, while the technical requirements for digital video production may now be less demanding, the production of quality learning content still requires appropriate expertise [9-10].

The first question that arises is that the role of video clips should be considered more an addition to other teaching materials than a replacement of the same. This question becomes important depending on the audience: while on-campus students are more likely to consider the video resources useful as extra information on the topic, off-campus students are more likely to consider that the video resources are useful in helping them to understand the issues involved in the topic [8, 11]. This may be due to the fact that on-campus students have easy access to lectures and academic staff, while off-campus students receive only printed or electronic study materials, and the availability of video resources may provide alternate viewpoint on the topic of study.

Another relevant question about the use of video resources is the format of the video. The format of the video can be considered in two ways: the length of the video and the recording setting. It is noted that the literature [10] recommends short video segments to maximize learners' concentration. Previous experiences reported in the literature [8] confirm this trend: it is preferable four segments video of 11-12 min duration than a video of 45 min of a full lecture. Respects the recording setting, two options are the most common for distribution: a) streaming video from a web site (for example, the university learning content management system) via broadband Internet access; and b) supply of CD-ROM or DVD version. Practical playback of the on-line video resources requires a broadband Internet connection, which on-campus students have access to in the university computer laboratories. However, due to a combination of price, technical availability and geographic factors, the uptake of home broadband Internet connections is comparatively low; hence CD-ROM or DVD would be expected as the preferred playback source for off-campus students.

When searching for video clips for teaching purposes, you can consider television broadcaster on-line resources, or websites such as YouTube, TeacherTube or BUFVC, which can be very useful. However, high level technical and/or educational videos are very scarce, and direct use of streaming videos for teaching could be inefficient for the learner if the video resource is not integrated in a comprehensive teaching approach. Further, though the use of videos is a move forward, passively observing a video is not cognitively engaging and challenging, and therefore learning is not as effective as it can be. Some interactivity should be desirable in video resources, promoting engagement and active involvement.

Most common use of integration of video resources in teaching engineering courses are related to on-campus experiences, but are very scarce when referred to e-learning, off-campus experiences. E-learning has recently become a promising alternative to the traditional classroom learning, helping society move toward a vision of lifelong and on-demand learning. Thousands of on-line courses are now being offered. Recent advances in multimedia and communication technologies have resulted in powerful learning systems with instructional video components. The emergence of non-linear, interactive digital video technology allows students to interact with instructional video. The concept is not new but is taking on new forms. However, the effect of interactive video on e-learning is still not well understood. Reference [12] describes a research mainly focused on investigating the impact of interactive video on e-learning effectiveness through an empirical study. A multimedia based e-learning system was used to teach a Management Information Systems course to freshmen, undergraduate students. Results of the experiment showed that the value of video for learning effectiveness was contingent upon the provision of interactivity. Students in the e-learning environment that provided interactive video achieved significantly better learning performance and a higher level of learner satisfaction than those in other settings.

But e-learning has also a great potential of use in life-long, postgraduate courses. It is the most frequent case for current professional engineers or architects. E-learning is partially a response to the demand for reduction in time-to-competency in the knowledge-based economy. Companies need to offer effective training to employees and business partners to ensure that they acquire new skills in a timely manner. The number of international e-courses is also increasing nowadays, due to the increase of professional mobility and the global economy. When using video resources in international courses, multilingual facilities are an added requirement for their integration in multimedia based e-learning systems. At present, none research on learning effectiveness of using video resources in teaching international, postgraduate e-learning engineering courses has been reported. This work is intended to carry out a study of the effectiveness of video resources on learning outcomes and learner satisfaction in e-learning engineering courses.

III. CASE STUDY OF INTEGRATING VIDEO IN AN E-LEARNING ENGINEERING COURSE

This paper presents a case study of development of video teaching materials for international, postgraduate engineering courses. The video will be put to the test in a postgraduate e-course entitled Solar Energy and other Renewable Energies in Buildings, within the Higher Polytechnic School of the University of Burgos. The pilot experience is designed to answer, amongst other, the question about what would be the students' usage during the course and what would be the implications of this experience for further developments.

During the period from November 2009 to March 2010, the University of Burgos will teach an international, full on-line course on Solar Energy and other Renewable Energies in Buildings, as partner of a European Union project. The project, entitled Novel and Integrated Model of Sustainable Energy Communities (NIMSEC), is focused on improving and surpassing the local level energy efficiency, and increasing the overall share of renewable energy production, especially in public buildings and/or industry and agriculture. Based on an analysis of the local framework conditions and on data collected in energy audits, concrete pilot actions are planned and implemented towards building integrated model of sustainable communities. Training courses on energy efficiency and renewable sources of energy will aim at university students on one hand and at technicians (energy auditors) and installers or distributors for renewable energy sources on the other hand.

The staff of the University of Burgos has previous experience in teaching international e-learning engineering courses, described in detail in the literature [13]. The present course will be addressed to engineers and architects who wish to become specialized in the field of the small Renewable Energy Sources applications in buildings. The learning content management system (LCMS) of the University for on-line teaching, UBUCampus-e, will be used for the delivery of the course. That implies a high grade of technical contents focused on renewable energy engineering topics. Besides electronic books and links to technical web sites, some multimedia presentation with interactive exercises and questionnaires, technical video and hypermedia tools will be included to promote active learning. In the previous experience [13], some technical or informative videos on renewable energies were included in the multimedia teaching tools. These videos, as obtained from free and public websites, were only partially related to the topics of the course, and, as a consequence, their use was considered only as complementary information on the topic. Locution was only in English language and no interactivity was allowable.

In this work, the authors have developed a pilot experience of a video on Solar Thermal Systems for Domestic Hot Water production to be used as teaching material in the next postgraduate e-learning course. When planning the teaching materials, some requirements of the video were established:

a) The video should be editted in several languages, accordingly to the international nature of the project.

b) The video should enable random access to its different parts, which is expected to increase learner engagement.

c) As a solar thermal system has no visible moving parts when fonctioning, some animations should be included to increase the visual impact of thermal concepts in the video.

d) Some kind of interactivy was desired, in conection with the learning outcomes and the assessment of the course.

e) Two versons of the video will be needed: first, one version with full facilities which will be distributed vía DVD and, second, an on-line streaming version of the video to be included in the LCMS of the University for those students with broadband Internet access.

Respect the video languages, it was decided to use only Spanish for the locution, because of the high costs of locution recording in other languages. Optional subtitles in English, French and also Spanish were then adopted as a solution to offer a multilingual video. Availability of subtitles has also a secondary benefit, thus this feature of the video increases the accessibility of the video for disabled people (deaf people).

In order to provide interactive video, logic segmentation of the instructional video into seven chapters was performed. If the learner does not interact, the whole video will automatically 'flow' from beginning to end. However, the learner can perform interactive operations at any time by pressing the control buttons of the media player used, going forward or back to the next/previous unit. The user can also directly jump to any particular video chapter by clicking the correspondent sub-topic in the menu tool-bar of the media player (i.e., random access to video content). As a result, interactive video eliminates the linearity of traditional video.

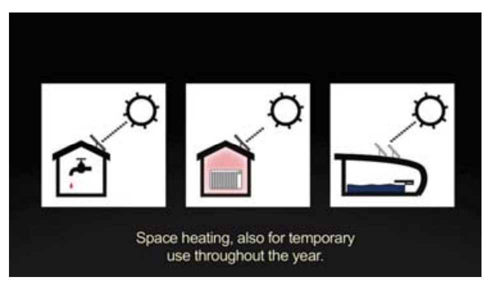
2D and 3D animations have been included as a dynamic approach to some critical thermal concepts of solar thermal systems, such as the energy balance and the green-house effect of the solar collector, or the explanations about the alternate uses of the low temperature solar thermal energy systems in buildings.

As a novelty of the instructional video, interactive questionnaires in Spanish, English or French languages are available in the main menu of the video. These questionnaires consist in multiple choice questions tests. The user clicks on the selected answer and the video offer an answer (correct or wrong) to the user. The question/answer process is visually reinforced with the change of the related picture appearing at the left side of the screen. These questionnaires are intended to be used as self-assessment exercises by the learner. The topics included in the questionnaires are related to the questionnaires and exercises that will be used in the assessment of the course.

Fig. 1 shows some examples of the features of the video described in the precedent paragraphs.

(a)

(b)



(c)

(d)

Figure 1. Examples of several features of the Solar Thermal System multilingual interactive video: (a) main manu page in Spanish language; (b) video footage with English subtitles; (c) 2D video animation with English subtitles; (d) interactive multiple choice questionnaire in French language

Recording of the video was produced in full HD quality with a camcorder. An experimental low temperature solar thermal system for on-campus teaching at the Higher Polytechnic School was used for the recordings. 2D animations were designed with After Effects CS3·software, while 3D Studio Max was used for 3D animations. Full HD plus 2D and 3D animations were integrated into video linear edition by means of Final Cut Studio2 editor.

Interactive questionnaires were first edited with Photoshop to combine pictures with text-boxes including the questions. Finally, encoding of video, questionnaires and all the facilities was done with Adobe Encores CS3, which manages all the menus and options of the user.

Codification in MPEG-2 was used to produce the DVD with full facilities described, of about 1 GB in size. In this format the video can be played in any commercial DVD player or in computer.. However, for distribution through the Internet, a version with compressed codification in MPEG-4, with no optional menus and only English subtitles, was produced.

Finally, a text file in pdf format has been also included in the DVD. This text is a printed version of the script of the video, so the learner can use it as a reinforcement tool during or after the video use. The text is available in Spanish, English and French.

Author's previous experience in e-learning engineering courses [13] is that self-study materials (including self-assessment procedures) are used frequently by the students during the course and receive, in general, a very high valuation as helping tool for learning. Usually, students that achieve a higher level of mastery in the topics of the course use more frequently and during more time the self-study materials than the rest of students. At the same time, their valuation of the self-study materials is directly related to the course assessment criteria and methods, activity where they will put their extra time and effort. Therefore, we expect that the effectiveness of the proposed video resource is higher respect the use of commercial, non-interactive videos or the use of no videos.

The streaming video will be included in a hypermedia tutorial conceived as a helping learning task in the corresponding module. The editor of these learning objects (exe.exe, eLearning XHTML editor) is a desktop authoring environment to assist teachers and academics in the creation of web content. The editor includes a range of pedagogical forms, e.g. objectives, advance organizers, and learning activities (text, videos, questionnaires, wikis, etc.), which constitute the equivalent of the 'teacher talk' in content resources designed for online learning. Some features of the hypermedia tutorial are presented in Fig. 2

(a)

(b)

(c)

Figure 2. Hypermedia tutorials on Renewable Energies in Buildings: (a) Objectives and pre-requisites to follow the tutorial; (b) Multiple choice test; (c) Reproduction of a linked scientific video.

The learning objective of the set of hypermedia tutorials is to broad the scope of each module and to present the information in an attractive and interactive way, in order to engage the student with the correspondent topic. Though the relevant engineering content of the course is included within the licensed e-books (texts of reference), the hypermedia tutorials are intended to allow students to go more deeply into the specific topic.

It is expected that 25 engineers or architects coming from 5 countries of the European Union will be involved in the course. It is very probably that, for many of them, this will be the first time they will follow a full internet engineering course; also, that they probably will have to use extra time after their current job to study the course.

A survey on the effectiveness of the video as teaching material and its integration in the e-learning course will be performed. Some data about the student engagement with the video will be collected by means of a perception test. The information will be gathered by the presentation of statements to which students were invited to respond on five-point scale ranging from ‘strongly agree’ (5) to ‘strongly disagree’(1). The questionnaire is conceived in order to elicit information about three dimensions of student’s engagement with the video tutorial: learning outcomes, technical matters and easiness of use. A preliminary perception test will be posed to each student at the early beginning of the course, when he has just got an overview of the course but not still begun with the required tasks. A second test will be posed at the end of the course, when the student had finished it, in order to compare changes in the student’s perception of the quality of the video tutorial, before and after using them. Scores of both pre- and post-tests will be examined through descriptive statistics. For students using the on-line streaming video distributed through the UBUCampus-e LCMS, the tracking facility of this system will be used to check every learner-content interactive operation with the interactive video

IV. Conclusions

A European postgraduate program on renewable energies in buildings, developed in an international cooperation project, is oriented to improve engineer’s ability to design and construct renewable energy systems in buildings and communities, along the period 2009-2010. The international course, with a high grade of technical contents focused on renewable energy engineering topics, is addressed to engineers and architects who wish to become specialized in the field of the Renewable Energy Sources applications. The LCMS of the University of Burgos for on-line teaching, UBUCampus-e, will be used for the delivery of the course.

A multilingual, interactive video on low temperature solar energy systems, conceived as a helping learning task, has been developed by the teachers, and is included within the course contents. The learning objective of this video is to present the information in an attractive and interactive way, in order to engage the student with the correspondent topic. Being of elective use, the video include technical description of the solar system, interactive questionnaires and additional text documents for self-study, aligned with the expected outcomes and the assessment of the course. Design criteria for learning effectiveness of the video are based on literature and previous experiences of the authors.

The pilot experience will be put into force during winter 2009 and spring 2010, using the interactive video within an e-learning engineering course on renewable energies. It is expected that 25 students from several European countries will be involved. A survey will be conducted to study if the video, which provides individual control over random access to content and offer optional self-assessment of learning, may lead to better learning outcomes and higher learner satisfaction.

Acknowledgment

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Session 10F VISIR Special Session : VISIR Special Session: Practical Workshop on VISIR electric and electronic remote labs

Workshop on VISIR electrical and electronic remote lab: Practical view

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Session 11A Area 4: Learning Models - Methods

Adaptive hypermedia systems for e-learning

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Applying an Inductive Method to a New, Multidiciplinary, Management of Innovation & Technology Course: Evidence from the University of Nicosia

Ktoridou, Despo
University of Nicosia (Cyprus)

Implantation of a Methodology based on Standard Supplements applied in Engineering Education

González-Aragón, Manuel; Sebastián-Pérez, Miguel Ángel; Sevilla-Hurtado, Lorenzo
Spanish University for Distance Education-UNED (Spain); University of Malaga (Spain)

yPBL methodology: a problem-based learning method applied to Software Engineering

Exposito, Ernesto
INSA-Toulouse (France)

Adaptive hypermedia systems for e-learning

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Abstract— **The domain of traditional hypermedia is revolutionized by the arrival of the concept of adaptation. Currently the domain of Adaptive Hypermedia Systems (AHS) is constantly growing. A major goal of current research is to provide a personalized educational experience that meets the needs specific to each learner (knowledge level, goals, motivation etc...). In this article we have studied the possibility of implementing traditional features of adaptive hypermedia in an open environment, and discussed the standards for describing learning objects and architectural models based on the use of ontologies as a prerequisite for such an adaptation.**

Keywords: e-learning, learner modeling, , adaptive educational hypermedia, ontologies, RDF, IMS LIP

I. Introduction

E-learning is a very dynamic domain, constantly growing, which refers to educational content or learning experiences delivered or made through digital technologies. The development of this domain has a direct impact on teaching quality and reducing costs. E-learning today is dominated by Learning Management Systems (LMS) such as Blackboard, Moodle, ATutor or Claroline, which are integrated systems that provide support for a wide area of activities in the e-learning process. Thus, teachers can use the LMS for course creation and test suites, to communicate with students, to monitor and evaluate their work. Students can learn, communicate and collaborate through LMS.

The problem is that LMS does not offer personalized services, presents the same educational resources to different learners, regardless of different levels of knowledge, interest, motivation and objectives. As Morrison [1] stated:"Just as people differ in many respects, so do ways in which they learn differ". Some of these differences are evident in the types of experiences that each person needs to learn. It is therefore essential to start the process of planning, attention to the characteristics, capabilities and experiences of learners - as a group and as individuals. "Adaptive Educational Hypermedia Systems (AEHS) try to provide an alternative approach to non-individualized, providing various services, tailored to the learner profile. The purpose of this adaptation is to maximize the subjective satisfaction of the learner, the learning speed (efficiency) and assessment results (effectiveness).

There are two basic questions in AEHS:

- What can we adapt to? The answer includes several learner characteristics, such as knowledge, goals, tasks or interest, background and experience, learning style, context and environment.
- What can be adapted? The answer includes the presentation (adapting the actual content, the presentation of that content, or the media used) as well as the navigation (adapting the link anchors that are shown, the link destinations, and the overviews for orientation support).

In addition, Adaptive hypermedia systems (AHS) for e-learning represent a continuously growing research domain, involving knowledge from several fields (adaptive systems, adaptive hypermedia, learning management systems, user modeling, educational psychology, instructional science).

Adaptation can take 3 forms [2]:

- Adapted systems: in which adaptation is hard-wired by the application designer; in this case, the system is customized to a particular user profile, which is defined beforehand, at design time.
- Adaptable system: in which adaptation is explicitly required by the user. More precisely, the user can specify her/his own preferences, by manually creating her/his profile; thus the system is dealing with a fixed profile, which can only be modified by user's intervention.
- Adaptive systems: in which adaptation initiative belongs to the system itself, based on continuous observation of user preferences and needs. The user's profile is no longer static, it is dynamically updated by the system, after tracking and analyzing user behavior.

II. ADAPTIVITY IN E-LEARNING

A conceptual definition of adaptivity in e-learning refers to the creation of educational experiences that adjust based on various conditions (personal characteristics, pedagogical approach, user interactions, learning outcome) during a certain amount of time in order to improve performance indicators (e-learning efficiency: results, time, costs, user satisfaction). The functional definition refers first of all to the main characteristics provided by the system. An adaptive system must be capable of managing learning paths adapted to each user, monitoring user activities, interpreting them using specific models, inferring user needs and preferences and exploiting user and domain knowledge to dynamically facilitate the learning process [3].

We can identify three major development paradigms in Artificial Intelligence in Education:

- Intelligent Computer-Assisted Instruction, using classic mainframes and mini-computers as platforms. The main goal of these systems was the transfer of knowledge to the student, therefore the learning material consisted mainly of presentations and also some exercises and problems. Correspondingly, the most popular technologies were curriculum sequencing and intelligent solution analysis [4].

- Intelligent Tutoring Systems, using personal computers as the support platform. The main goal shifted from educational material presentation to supporting the student in solving problems and procedural knowledge formation. Consequently the core technology became interactive problem solving support.

- Web-based educational systems, having the WWW as support platform. The goals of these systems became more complex and diverse, including at the same time content delivery, problem solving support and collaborative work support. Consequently multiple technologies were employed, ranging from adaptive curriculum sequencing, adaptive hypermedia, adaptive information filtering, intelligent solution analysis, intelligent collaborative learning, class monitoring.

Our research is oriented towards the adaptive and intelligent Web-based educational systems. Adaptive systems are those systems that try to behave differently toward each student, based on the information accumulated in the student model, while intelligent systems apply artificial intelligence techniques in order to comply with the needs of their users.

III. ADAPTATION COMPONENTS

In what follows, we present the components of adaptation, to examine briefly adaptation levels and technology, adaptation models and ways of representing adaptation knowledge.

A. *Adaptation Levels and Technologies*

A method is defined as a notion of adaptation that can be presented at the conceptual level. A technique is a way to implement a specific method. Techniques operate on actual information content and on the presentation of hypertext links. It may be possible to implement the same method through different techniques and to use the same technique for different methods [5].

According to the most recent classification there are two levels of adaptation:

- Adaptation to the level of content and presentation adaptation
- Link level adaptation navigation or support adaptation.

Indeed, by abstracting hypermedia as a graph, we can either adapt its nodes (content level adaptation) or its edges (navigation level adaptation). Figure 1 provides a summary of the adaptive hypermedia technologies.

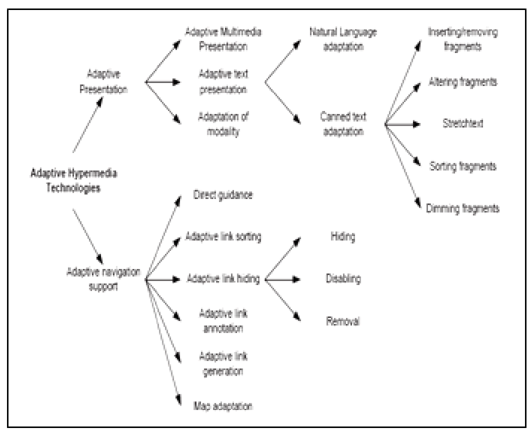

Figure 1. Updated taxonomy of adaptive hypermedia technologies [6]

While the distinctions of the taxonomy are important for identification and classification of adaptive systems, the implementation of these techniques can be achieved using a small selection of fundamental data structures that can be combined to create powerful AH systems.

B. *Adaptation Models*

The Adaptive Hypermedia Application Model (AHAM) provides a framework to express the functionality of adaptive hypermedia systems by dividing the storage layer into three parts that specify what should be adapted, according to what features it should be adapted, and how it should be adapted.

The Munich Reference Model preserves the three-layer structure of the Dexter Model describing the network of nodes and links and the navigation mechanism. It extends the functionality of each layer to include the user modeling and adaptation aspects. The Run-Time Layer, the Storage Layer and the Within-Component Layer are represented as UML subsystems as it is illustrated in Figure 2.

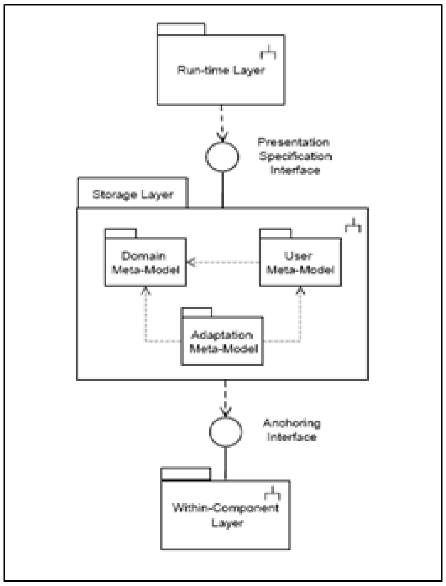

Figure 2. Architecture of Adaptive Hypermedia Applications

The Run-Time Layer contains the description of the presentation of the nodes and links. It is responsible for user interaction, acquisition of user behavior and management of the sessions.

The Storage Layer has more functionality than just storing information about the hypermedia structure. To support adaptation the Storage Layer is divided into three sub-models:

- The Domain Meta-Model that manages the basic network structure of the hypermedia system in terms of mechanisms by which the links and nodes are related and navigated. The nodes are treated as general data containers.
- The User Meta-Model manages a set of users represented by their user attributes with the objective to personalize the application.
- The Adaptation Meta-Model consists of a set of rules that implement the adaptive functionality, i.e. personalization of the application.

The content and structure within the hypermedia nodes are part of the Within- Component Layer, which is not further detailed as its structure and content depend on the application. The functionality of adaptive hypermedia systems is specified by three types of operations included in the classes of the reference model:

- Authoring operations are needed by adaptive hypermedia systems to update components, rules and user attributes, e.g. to create a link or a composite component, to create a rule, to add an user attribute to the model, to delete components or rules.
- Retrieval operations are required to access the hypermedia domain structure and the User Model, e.g. to get a component, to get all rules triggered by a user's behavior or another rule.
- Adaptation operations are used to dynamically adapt the User Model content to the user behavior and to adapt the presentation to the current state of the User Model, e.g. the adaptive resolver, the constructor or the rule executor.

The remainder of this paper presents the visual specification (slightly simplified) of the layers of the reference model and includes a few constraints of the formal specification out of a total of seventy constraints that comprise the complete specification of the Munich Reference Model [7].

C. Representation of Adaptation Knowledge

We can identify several ways of addressing the issue of procedural knowledge, for more detail see [8]; in our case we are interested in the use of ontologies. Because, from our point of view, different types of knowledge relevant to the adaptive learning could be represented using ontologies based on the use of Resource Description Framework (RDF).

There are several authors that propose the use of ontologies, such as Cristea [9] (appropriate ontologies for each layer of the LAOS model, namely: domain, goal and constraint, user, adaptation, and presentation ontologies), Henze et al.[10] (domain ontology, user ontology, observation (interaction) ontology and presentation ontology).

IV. Integrating Adaptive Hypermedia Techniques

In this section we discuss the possibilities of using standardized metadata to describe and classify information stored in a Resource Description Framework database to describe the knowledge, preferences and experiences of users accessing that information. In addition, we will illustrate how to implement features of adjustment with the ultimate goal of implementing a personalized access to learning.

A. Using RDF Metadata

Resource Description Framework (RDF) is a graph model for formally describing Web resources and their Metadata, to enable automatic processing of such descriptions. Developed by the W3C RDF.

A document structured in RDF is a set of triplets. An RDF triple is an association: {subject, predicate, object}

- The subject is the resource to describe;
- The predicate is a type of property applicable to this resource;
- The subject is given one or another resource: the value of the property.

To annotate resources, we have identified a subset of best practices of 15 elements which are summarized in Table I, using the categories defined in the LOM [11]. It was found that these 15 attributes are enough to annotate and query our resources, and represent a compromise between sets of annotations more abstract and more detailed. Annotations of an entire course can be included in a single RDF file. All RDF triples are then imported into a relational database to customize the display of resources and to ask others.

TABLE I. THE 15 ATTRIBUTES TO ANNOTATE AND QUERY OUR RESOURCES

General	Title	**dc:title**
	Language	**dc:language**
	Description	**dc:description**
Lifecycle	Contribute	**dc:creator** with a **lom:entity** and the author in vCard format "name surname" dcq:created with the date in W3C format
Rights	Description	**dc:rights**
Relation		**dcq:hasFormat** **dcq:isFormatOf** **dcq:hasPart** **dcq:isPartOf** **dcq:hasVersion** **dcq:isVersionOf** **dcq:requires** **dcq:isRequiredBy**
Classificatio n		**dc:subject** for content classification. This attribute links to an entry in a hierarchical ontology, that is an instance of **lom_cls:Taxonomy** (see next section)

B. *Topic Ontologies for Content Classification*

Personalized access means that resources are tailored according to some relevant aspects of the user. Which aspects of the user are important or not depends on the personalization domain. For educational scenarios it is important to take into account aspects like whether the user is student or a teacher, whether he wants to obtain a certain qualification, has specific preferences, and, of course, which is his knowledge level for the topics covered in the course.

Taking user knowledge about topics covered in the current account is complicated, because it requires Cognitive Styles (see also [12]). The general idea is that we annotate each document by the topics covered in this document. Topics can be covered by sets of documents, and we will assume that a user fully knows a topic if he understands all documents annotated with this topic.

To be more general, we use ontologies that are already part of classification systems are internationally recognized.

ACM CCS as a topic ontology for learning objects. The ACM Computer Classification system ([13]) has been used by the Association for Computing Machinery since several decades to classify scientific publications in the field of computer science. On the basic level, we find 11 nodes that split up in two more levels.

To classify a resource, the IEEE Learning Object RDF Binding Guide ([14]) suggests the use of *dc:subject* with elements of a taxonomy that must be found on the Internet. Such a taxonomy hierarchy is an instance of *lom-cls*:*Taxonomy* and must be formatted in a RDF file where the topics and subtopics are separated using *lom_cls*:*Taxon* and *lom_cls*:*rootTaxon*. As discussed, we used ACM CCS, The main structure is as follows (Figure3):

```
<dcq:SubjectScheme rdf:ID= ACM CCS >
<rdfs:label>ACM Computer Classification system</rdfs:label>
</dcq:SubjectScheme>
<lom_cls:Taxonomy>
  <lom_cls:rootTaxon>
  <ACM:ACM CCS rdf:about= http://www.lnte.org/
  Prototype/ACM CCS.rdf#D >
  <rdf:value>Software</rdf:value>
      <lom_cls:taxon>
      <ACM:ACM CCS rdf:about= http://www.lnte.org/
       Prototype/ACM CCS.rdf#D.1>
      <rdf:value>PROGRAMMING TECHNIQUES
      </rdf:value>
         <lom_cls:taxon>
         <ACM:ACM CCS rdf:about= http://www.lnte.org/
           Prototype/ACM CCS.rdf#D.1.1.6>
         <rdf:value>Logic Programming
         </rdf:value>
         </lom_cls:taxon>
      </lom_cls:taxon>
  </lom_cls:rootTaxon>
</lom_cls:Taxonomy>
```

Figure 3. Use of ACM CCS : Main structure

C. *Describing Users*

In recent years there have been some efforts to standardize the information about a user, which should be maintained by a system.we choose the IMS Learner Information Package [15].

IMS LIP is a structured information model. An XML binding is included but is not meant to exclude other bindings. The information model contains both data and meta-data about that data. The model defines fields into which the data can be placed and the type of data that may be put into these fields. Typical data might be the name of a learner, a course or training completed, a learning objective, a preference for a particular type of technology, and so on.

The Learner information is separated into eleven main categories (as shown in Figure 4). These structures have been identified as the primary data structures that are required to support learner information. This composite approach means that only the required information needs to be packaged and stored.

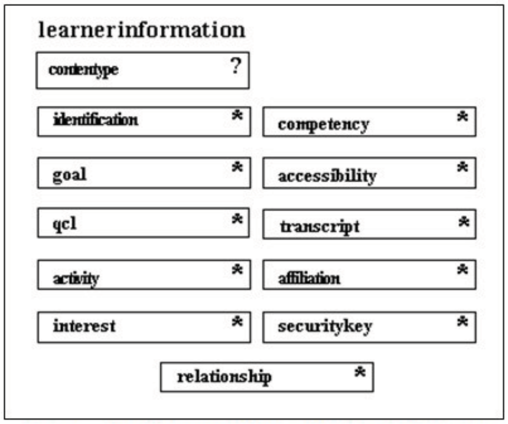

Figure 4. The IMS Learner Information Package (LIP) core data structures

An example of accessibility category data is represented in Figure5.

```
<learnerinformation>
  <contentype><referential>
      <sourcedid><source>
          IMS_LIP_V1p0_Example
        </source>
        <id>basic_1001</id>
      </sourcedid></referential>
  </contentype>
  <accessibility>
    <contentype><referential>
        <indexid>accessibility_01</indexid>
    </referential></contentype>
    <language><typename>
        <tysource sourcetype="imsdefault"/>
    <tyvalue>Frensh</tyvalue></typename>
      <contentype><referential>
          <indexid>
            language_01
          </indexid>
      </referential></contentype>
      <proficiency profmode="OralSpeak">
        Excellent
      </proficiency>
      <proficiency profmode="OralComp">
        Excellent
      </proficiency>
      <proficiency profmode="Read">
        Good
      </proficiency>
      <proficiency profmode="Write">
        Poor
      </proficiency>
    </language></accessibility>
</learnerinformation>
```

Figure 5. An example of LIP Accessibility information.

The *identification* category represents demographic and biographic data about the user. The *goal* category represents learning, career and other objectives of the learner. The *QCL* category is used for identification of qualifications, certifications, and licenses from recognized authorities. The *activity* category can contain any learning related activity in any state of completion. The *interest* category can be any information describing hobbies and recreational activities. The *relationship* category aims for relationships between core data elements. The *competency* category serves as slot for skills, experience and knowledge acquired. The *accessibility* category aims for general accessibility to learner information by means of language capabilities, disabilities, eligibility, and learning preferences. The *transcript* category represents institutional-based summary of academic achievements. The *affiliation* category represents information records about membership of professional organizations. The *security key* is for set passwords and keys assigned to a learner.

V. System Description

Our system is under development, we present here a primary prototype interface. (Figure 6)

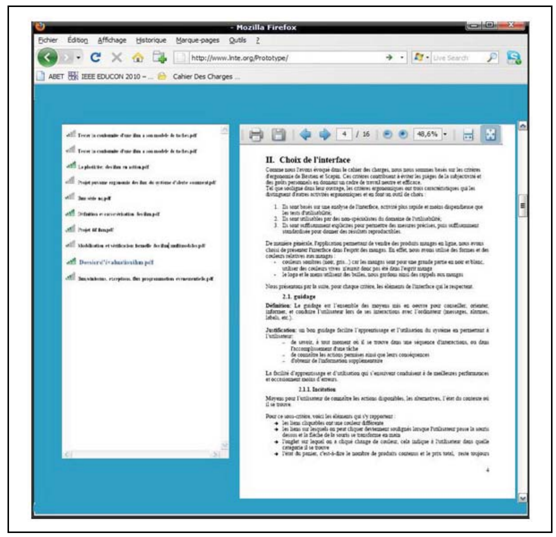

Figure 6. Protoype of the user interface

Information will be presented in two different frameworks. The left frame displays the course structure based on metadata. The user can navigate through this structure and can open documents in the right frame. Each resource is annotated according to the current user profile to express its relevance to the user. For annotations, we use a metaphor of wireless connection.

VI. conclusion

In this article we have studied the possibility of implementing traditional features of adaptive hypermedia in an open environment, and discussed the standards for describing learning objects and architectural models based on the use of ontologies as a prerequisite for such an adaptation.

We discussed how this information can be expressed as RDF metadata and how we can use queries over this metadata. We also discussed the architecture of our hypermedia all based on the Munich Reference Model. We finally present our system (adaptive hypermedia), which has been implemented as a prototype.

In our work, we will continue to improve links RDF. We will also experiment with compositions of resources and techniques of presentation and adaptation of different types of applications tailored functionality.

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Applying an Inductive Method to a New, Multidiciplinary, Management of Innovation & Technology Course: Evidence from the University of Nicosia

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Abstract—Managing **Technological innovation is one of the most important aspects of business for management, business, management information systems (MIS), engineering and science students to learn. Academics and practitioners, who teach topics related to technology innovation to multidisciplinary classes, usually they do so deductively, that is the lecturer introduces the general principles and continues with applications of those principles. A common observation is that University students do not see any motivation knowing that someday they will need those knowledge and skills. A *Student-centered teaching method* on the other hand shifts the focus of activity from the lecturer to student including *inductive teaching* and learning.**

The new, elective "MGT370- Management of Innovation and Technology" course was to engage students from different specializations in a collaborative environment in which students have access to assignments based on real-world case studies and problems. After a group open-discussion a preliminary analysis of students' perceptions towards technology innovation content knowledge faced a significant contradiction.

This paper presents a review of the unique features of the main inductive methods, describes the new elective Management of Innovation and Technology course, presents assessment outcomes, reports the learning outcomes after the employment of inductive learning strategies in the course and gives recommendations on how assessments are being used to deploy, manage and improve the course.

Keywords-problem-based learning; technology innovations; student-centered method; inductive teaching and learning method;

I. INTRODUCTION

Academics and practitioners who teach specializations such as MIS, and Science traditionally do so deductively. Students are introduced to theory and mathematical models and then are given exercises from the textbook and possibly some real-world cases/applications to analyze. A general observation is that teaching technology innovations to multidisciplinary classes generates questions on whether any real world cases could be explained; can any practical problems be solved; does all this knowledge meet the interests of a multidisciplinary class; and finally is it really a motivation telling students that they will need certain knowledge and skills someday [1]. Is it really motivating to know that what they are learning will be useful for their curriculum and further for their careers? Based on references [2] and [3] the most common reason for students to leave sciences is the lack of connecting the course material to the real world.

A student-centered approach where the student is responsible for his/her own learning by building his/her own version of reality is an alternative approach to learning. Specifically a student-centered approach includes inductive teaching and learning where students are primarily presented to a precise challenge, like a real-world case study to analyze, seek a solution to a complex illustrated open-ended real-world problem or interpretation of experimental data. While dealing with these challenges, students realize that they lack skills, knowledge, facts and conceptual understanding and they request the help of the lecturer, who plays the role of the facilitator. Based on references [4], [5] and [6] it is demonstrated that inductive methods encourage students to adopt a deep approach to learning that lead to further intellectual development. Inductive teaching and learning incorporates the following learning methods: inquiry, problem-based, project-based and discovery as wel as case-based teaching and just-in-time teaching. Prince and Felder [1], one of the few who have examined these methods as a group, have reviewed several of the most commonly used inductive teaching methods defining each method, highlighting commonalities and specific differences, and reviewing research on of their effectiveness for and science education.. This paper presents a review of the unique features of the main inductive methods, describes the practical applications of: inquiry learning, problem-based learning, and case-based teaching in the new elective course MGT-370 Management of Innovation and Technology and discusses practical issues of implementation specifically in meeting the needs of a multidisciplinary class. Finally it attempts to evaluate the effectiveness of the various activities. Recommendations are given to academics and practitioners for designing their curriculum based on a student-centered approach using inductive methods for: the development of critical thinking and creative problem-solving skills, a deeper understanding for formation of positive attitudes and confidence in knowledge or skills toward the course [1].

II. LITERATURE REVIEW

A. *Student Centered Teaching Methods*

During the last few decades, education literature presents a broad variety of student-centered teaching methods and presents evidence that a proper implementation of a student-centered method could lead to: rise of motivation towards learning with more positive attitudes toward the subject, greater retention of knowledge and deeper understanding [8,9,10,11].

Student-centered teaching methods shift the focus of activity from the teacher to the learners. These methods include active learning, competitive learning and inductive teaching and learning placing the emphasis on learning instead of teaching. Academics and practitioners are continuously seeking ways to enhance, enrich their classes as well as motivate their students. More specifically, in higher education, for an elective Technology course, taken by business, management, management information systems (MIS), and science students, one approach is to be such targeting to an assessed short-term mastery, a depth of course material understanding, critical thinking acquisition, creative problem-solving skills, formation of positive attitudes toward the subject, and level of confidence in knowledge or skills.

B. *Inductive Methods*

Inductive teaching and learning include a range of instructional methods: inquiry-based learning, case-based instruction, problem-based learning, project-based learning, discovery learning, and just-in-time teaching. All these methods are all student-centered; are initially presenting to students challenges (questions or problems) and continue with studying the course material in the context of addressing these challenges. In class students are actively involved in discussing questions and solving problems (*active learning*), while in and out of class the work is done in groups (*collaborative learning*). [1] have summarized in a table the features of common inductive teaching methods Table I.

TABLE I. Source Journal of Education 95(2), p. 124

Method► / **Feature▼**	**Inquiry**	**Problem-based**	**Project-based**	**Case-based**	**Discovery**	**JITI**
Questions or problems provide context for learning	1	2	2	2	2	2
Complex, ill-structured, open-ended real-world problems provide context for learning	4	1	3	2	4	4
Major projects provide context for learning	4	4	1	3	4	4
Case studies provide context for learning	4	4	4	1	4	4
Students discover course content for themselves	2	2	2	3	1	2
Students complete & submit conceptual exercises electronically; instructor adjusts lessons according to their responses	4	4	4	4	4	1
Primarily self-directed learning	4	3	3	3	2	4
Active learning	2	2	2	2	2	2
Collaborative/cooperative (team-based) learning	4	3	3	4	4	4
1 – by definition, 2 – always, 3 – usually, 4 – possibly						

The differences among the above mentioned inductive methods are obvious. In the literature each method has its own research base, history, guidebooks, supporters, and critics, and is not clear what the methods are and how they are interrelated [1]. Lohman [12] claims that similarities of case-based and problem-based learning are obvious; however, in problem-based learning students are confronted with poorly structured problems driving to acquisition of new content knowledge while in case-based learning students analyze hypothetical situations, well structured, detail context-rich, involving solutions to problems and/or decision making. Katsikitis *et al.* [13] comparing case studies to problem-based learning found no significant difference between the two methods as far as performance or knowledge acquisition. The following paragraphs summarize definitions and applications of inquiry, problem-based and case-study learning methods that have been implemented in this paper.

Inquiry Learning- The focus of inquiry learning is on answering questions, solving problems, or explaining a set of observations [14]. Lee [15] in his work states that students should learn to "formulate good questions, identify and collect appropriate evidence, present results systematically, analyze and interpret results, formulate conclusions, and evaluate the worth and importance of those conclusions" only after an effective implementation of the method. Similar outcomes could derive after an effective implementation of a problem-based learning as well as certain forms of case-based instruction.

In this paper *inquiry learning* is implemented *as an instruction tool* using questions and problems providing contexts for learning strategies in ways of using strategic management of innovation to enhance firms performance.

Problem-based Learning – This approach to teaching offers students opportunities to learn via contextualized problem sets and situations. Through the group work and independent investigation, they achieve higher levels of comprehension, develop more learning, knowledge-forming skills and social skills. Lessons may be designed using different scenarios such as: a) entire class discussion b) group of students reporting their progress on earlier learning issues and listing their present learning issues and future plans of work, (c) short lectures on group work, aiming to keep class up-to-date on general issues, clarify common difficulties, as well as suggest additional learning issues [16].

According to meta-analysis of the effectiveness of problem-based learning done by a group of scientists [19], 43 empirical studies were identified having effects on problem-based learning, knowledge acquisition and development of problem-solving skills,

This paper discusses the implementation of a problem-based learning using problems that vary significantly in scope, from single-topic single-discipline problems to multidisciplinary problems that meet the needs of a multidisciplinary class.

Case-Based Learning - cases teach students about realistic decision-making situations involving one or more challenges: diagnosing technical problems and formulating solution strategies, making business management decisions taking into account technical, economic, and possibly social and psychological considerations, and confronting ethical dilemmas [1]. The cases should be real-life —situations based on professional practice coming out of magazines, newspapers or interviews from those involved in the case.

The idea of using real-world case studies, on technology innovations, in this course was based on Lundeberg, Levin and Harrington, [1] work stating that with real world case-studies students will be able to:

- analyze complex real-world cases,
- acquire theoretical and practical understanding of the subject
- become aware of the kinds of situations possibly facing as professionals in the future,
- develop critical reasoning skills,
- explore their existing preconceptions, beliefs, and patterns of thinking, and
- make necessary modifications in those prejudices, beliefs, and patterns to accommodate the realities of the cases.

C. Management of Innovation and Technology Course

MGT-370 is an undergraduate elective course under the management specialization. The main objectives of the course are

- Introduce of the important role of technology innovation in the Management strategy
- Understand the theoretical knowledge underlying the technological change and the ways firms come up with innovations
- Provide an overview of the strategies that firms use to benefit from innovation
- Understand the importance and role of formulating technology strategy**;**
- Design, develop and integrate a strategic management of innovation and technology

III. RESEARCH METHODOLOGY

To address the research objectives of the study a case study design was employed [7]. A case study based on Merriam;s [17] work that research focuses on discovery, insight and understanding from the perspectives of those being studied offers the greatest promise of making significant contributions to the knowledge base and practice of education.

With the qualitative case study research the researcher has approached the problem of a newly introduced technology innovation course to a multidisciplinary class, a problem of practice from a holistic perspective in order to gain an in-depth understanding of the situation and its meaning for higher education lecturers. The attention was focused in the teaching/learning processes rather than learning outcomes, in the general course context rather than some variable and in the process of discovery rather than in conformation.

The research method was designed to answer the question, how do students from different specializations in an inductive learning environment perform, collaborate, exchange ideas and acquire the subject.

The new course, MGT 370, management of Innovation and Technology was offered two times per week, sessions of 75 minutes each, to a multidisciplinary class of 10 undergraduate students. The curriculum was designed based on a student-centered approach including an inductive teaching and learning method.

To measure students' perceptions towards subject matter learning at the beginning of the course a pre-test has been completed to asses their conceptual knowledge of the principles of applying strategic management of innovation in a firm. Further based on the objectives of the course students worked, individually and in groups on question answering, situation exploration, realistic decision-making situations, contextualized problem sets and situations.

The classroom activities and Outcomes questionnaires provided data on student attitudes toward collaborative learning, problem-solving activities, and interaction with the lecturer and peers.

IV. DATA ANALYSIS

Based on the sample of the study the analysis of the results was made based on group work skills, communication and problem solving skills and content learning. The lecturer has moderated students work in class and has documented the pre-test results as well as their assessment results. see Table. 2

Inquiry Learning*:*

Students were given a question or problem based on real world technology evolutions as well as technology adoption sand diffusion or they have suggested a technological innovation of their preference so as to formulate good questions, search and gather suitable evidence, present results systematically, analyze and interpret results, formulate conclusions.

- *group work skills -* Science students reported that for such kind of assessments they prefer to work individually because they seem to have different preferences and knowledge towards technology innovations; they could formulate and structure in a different why their questions as well as search, gather, analyze and especially formulate conclusions.
- *communication -* Business and management students proved to be more communicative towards science

students and were suggesting real-life problems from businesses.

- *problem solving skills* – all students were thinking creatively and critically about ways to solve the given problem. Difference in backgrounds helped students to approach different related solutions fact that enabled them to analyze and interpret and present the results systematically.
- *content learning* – Content learning for all students was significantly satisfactory based on the discussion that derived at the end of the class.

Problem-based learning:

Contextualized, complex, open-ended, authentic problem sets on sources of Innovation and selection of innovation projects were presented to students individually and/or in groups for investigation. A class discussion followed as well as a group progress report on earlier/present learning issues and future plans.

- *group work skills* – students in some problems were asked to work individually and then join their peers into groups (coming from various disciplines) to exchange their findings, come up with a common solution and report it. It was interesting to note that the combination of independent investigation and group reporting led students to report solutions based on a combination of technical, business, management way of thinking and the reports were quite satisfactory having a professional view.
- *problem-solving skills* - based on the final group report, the observation was that students have reached a level of analytic comprehension through problem-based work.
- *communication* – During discussions for the development of the group reports students seemed to have shown resistance in sharing their investigation results. This basically derived from differences in the way they have approached the given problem and came up with solutions..
- *content learning* – the solution of problems based on the aims and objectives of the course required knowledge and skills. The complexity of the problems intrigued students, forcing them to go deeper into research to find and integrate material from various related sources so as to come up to a solution. This way students gained a better understanding of the courses content, developed problem-solving professional skills and have broadened their subject knowledge.

Case-based learning:

Real-world cases on technological innovations from the Harvard School of Business database were given to students targeting to expose them to the analysis of complex real-world cases, situations that they may possibly face as professionals in the future. Exploring, analyzing and discussing case real life situations students can better acquire theoretical and practical understanding of the subject and develop critical reasoning skills. Through initially individual work that was followed by group discussions and then group presentations, students will explore their existing ideas, beliefs, and thinking models so as to be flexible and make alternations their existing ideas, beliefs, and thinking models towards the realities of the cases

- *group work skills* –Students have analyzed the given case studies individually and then joined groups, again coming from different disciplines cases, so as to prepare for a group presentation. A noticeable exploration of beliefs, idea different way of thinking and analyzing the given situation led some students to disagreements. The lecturer who was working as a facilitator had to interfere and moderate the discussions clarifying some issues on the realities of the case targeting the modification of students' ideas, beliefs and thinking models so as to arrive to a common solution for presentation.
- *Problem solving skills* - Individual work on cases though has developed students' abilities in identifying relevant issues and improved their reasoning and problem-solving skills. Exploring, analyzing and discussing real life situations students have developed critical reasoning skills in finding creative solutions. It is interesting to note that if compare case studies to problem-based learning there were no major differences between the two methods related to performance or content learning.
- *Communication* - communication among students during the second stage of the case-based lesson plan was not satisfactory enough due to differences in educational background ideas, beliefs and thinking models. Some students have shown dissatisfaction in having to collaborate in their case analysis results with peers having different specializations.
- *content learning* – by exploring real-life cases, discussions of the results with peers and group presentations the performance of the students indicated gains in theoretical and practical understanding of the subject as well as case studies students' ability to recognize multiple perspectives was enhanced. Using cases developed students' ability to identify relevant to the content issues and exposed them to experiences and problem based situations.

V. CONCLUSION

Transformations from teacher-centered to student centered learning involves fundamental changes for both students and lecturers.

The inductive method used for this empirical study incorporated Inquiry learning - observations, problem-based learning – contextual complex problem solving, and case-based teaching – real-life case analysis.

Inquiry learning proved to be the approach that required a lot of effort from the lecturer in designing the context, based on questions and problems.

Problem-based learning incorporated complex, open-ended, authentic problems whose solution requires knowledge and skills specified in the courses aims and objectives. A variety of interpersonal problems had been raised during this method due to multidisciplinary educational background in group-work.. The lecturer must interfere as a facilitator to help student groups become effective teams targeting the development of students' professional skills such as problem-solving, and self-directed or lifelong learning.

The use of cases proved to be effective for the current elective undergraduate course with a multidisciplinary audience since learning aims and objectives incorporate decision-making in complex authentic situations. The selection of cases must address the learning aims and objectives with a wide variety of scenarios, had been raised such as identifying technical problems, developing solution strategies and making business management decisions.

The adoption of inductive methods can not reassure better learning and satisfaction for both lecturer and student. Any new teaching method should be very well planned, organized and implemented to meet the needs of the curriculum and students.

Students exposed to this methods that require more individual work full responsibility of their actions and minimum guidance must feel the lecturer as the facilitator who at the right time will offer them appropriate amount of guidance and support.

Lecturers deciding to implement inductive methods in their curriculum, they must search for cases, problems, complex situations that are based on real life scenarios that will offer students opportunities to exchange ideas, believes, knowledge, experiences and come up with professional solutions.

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Implantation of a Methodology based on Standard Supplements applied in Engineering Education

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Abstract— **This paper present a model for the integration for the standardization integration inside the technical teaching in university context, taking into account the established requirements by the European Higher Education Area (EHEA). This methodology is based on the development of a new typology of document named as "standard supplement". The proposed methodology serves to identify the set of documents witch are necessaries in a specific subject, the knowledge, abilities and attitudes to identify with the academic competences, previously defined, and a guide for the development of the contents of each "standard supplement". The proposal structure of "standard supplement" is appropriate to different level of complexity and could be used as a link between enterprises and engineering education.**

Keywords: Standardization, EHEA, Engineering Education

I. Introduction

The EHEA shows an important change in the traditional methodology implemented at the universities. Nowadays, Master class is the most used pedagogical practice in the university. It consists of an expositive method where teacher explains a subject and student take a passive attitude. In this case, teacher has all the responsibility to prepare the subject.

Obviously, to make a change from this teaching method, which is based on the traditional expositive method, with low student participation, into a new teaching method with high level of student participation, is very difficult. This change is impossible to achieve if is based only on a methodological aspect. In order to allow an active implication of the students in their learning, their effectiveness depends on a high level in their personal work. For this reason, the didactical material plays an important roll if it is structured to influence in their attitude.

Actually, the use of standards and standardization field is lower that it could be desired in engineering education, perhaps its high interest in technical learning. For this reason, the main objective of this work is to develop and to introduce a methodology for the integration of standardization in technical education [1, 2].

Technical teaching can not be understood without a constant allusion to standards that, in most cases, establish conditions or restrictions related to a specific topic. The incorporation of additional viewpoints in the contents of standards could be considered as an important advance in the present proposal. This paper can offer a continued flow of updated knowledge, transforming the current pure normative feature in another in which coexists the normative one with the pedagogical one.

This methodology is based on the development of a new typology of document named as "standard supplement" [3]. The incorporation of standard supplement should be understood from the perspective of the educational innovation, to increase the presence of the standardization in technical teaching and documents, by means of the elaboration of documents with all the necessary requirements established for the conformation of an European Higher Education Area (EHEA) [4–7].

The election of the subject of Internal Combustion Engine (ICE), among lots of subjects in technical teaching (electricity, electronics, machine tools or automobile fields) is based on the high number of implicated knowledge fields.

II. Methodology

The methodology proposed can be divided into three phases. The first one will characterize the necessary standard supplements for the development of the specific matter; second phase identifies academic competences that should be included in standard supplements; at last, third phase shows a guide to develop the content of standard supplements.

A. Characterization

The characterization of standard set to the development of a specific matter is carried out by means of a classification of the different elements to standardize. This classification depends on every matter and should show the relationship among elements (material composition, position, functionality, manufacture) or other technical criteria, and it should help to give an hierarchical structure, being useful to relate the function that every element has in its set and establishing the interrelation among their different systems.

There are different ways to classify the elements of an ICE. The engine is an important part of a vehicle, being formed by great number of elements and auxiliary systems. This proposal is based on a functional and positional classification of elements, according to technical criteria.

Positional relationship establishes a distribution of elements according to physical position of every element in engine, establishing distinction between external and internal elements.

In one hand, basic external elements shape the structural base, being used profusely as a support for the fixation of auxiliary systems and other elements. Cylinder head and the engine block are significant examples of these elements. On the other hand, internal elements are usually hidden, for example, cog-saft and connecting rod.

Functional relationship is established according to the relative movement of connection among elements, classifying them in "active" elements, if there is a relative movement, and "passive" elements, when there is no relative movement between them.

Main active elements transform thermal power of the fuel in mechanical power. They are situated inside the engine, so they can not be identified to simple view; for example: piston, connecting rod and crankshaft.

They are several series of auxiliary systems in an ICE. Some systems are essential for engine operation, as cooling system, whereas other systems help to optimize their operation, as variable admission system. The most of the elements of auxiliary systems can be included in one of the precedent groups, establishing the positional or functional relationship between engine elements and auxiliary system elements.

The creation of the fourth group is necessary to include other elements not mentioned in precedent classification, as pulley check, cylinder head gasket or plain bushings.

Previous considerations lead us to the need of creation of the next four groups:

- Group I. Active elements

- Group II. External elements

- Group III. Auxiliary systems elements

- Group IV. Other elements

Fig. 1 show positional and functional relationship, that is, the interrelationships established among elements belonging to the same group and among different groups' elements. The identified classification is generated associating concentric way identities. The functional or positional relationship is reflected by means of the union segments among elements. For this way, active elements (group I) have been represented inside the internal circle (green color); external elements (group II) are inside the second circle (blue color); finally, auxiliary systems elements (group III) are outside circle (orange color).

It can be noticed the existing functional relationship among active elements, being evident the dependence among them, because all elements are related. Active elements are in the center of the classification because they are considered as essential elements in an ICE.

The situation in the diagram of group II, corresponding to external elements, is justified for the positional relationship among these elements, given that support elements of group I (active elements) and the most of auxiliary systems elements.

Group III is situated in the last level of the diagram. Every auxiliary system is formed by a series of external or internal elements, actives or passives, with a positional relationship with elements of group II.

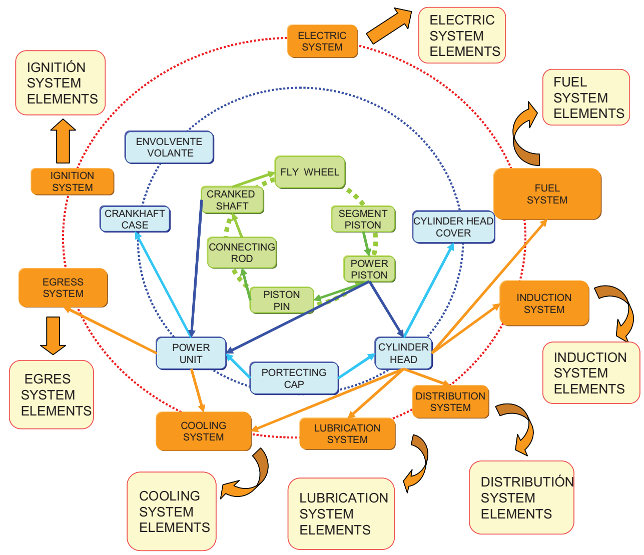

Figure 1. Positional and functional relation

B. *Contents*

Technical document presents, in most cases, references to standards that should be achieve, values that should be established, or allowed limits values. However the use of a standard is reduced, many times, to a simple reference. In the development of this proposed work, it is expected that the standard could be applied in other additional fields, with special attention to teaching context, because it is our point of reference, without underestimating of other possible ones.

The objective of this proposal is not to cancel or to modify the current standard contents, but adding an additional part in the standard supplement, where it is reflected, for each standardized element, the knowledge is considered necessary to be assimilated by an university technical education student, on the EHEA perspective. Due to they can find requirements in the technical educations in different levels, the development of the standard supplement may should have them in consideration, and to do so these requirements are included in this document.

This widening does not only consist of moving knowledge from a determined subject to the corresponding standard. Moreover, it is necessary to move requirements for the new teaching way. To achieve this, it adapts EHEA requirements in the standard content.

The development of aspect as:

- Methodological plurality

- Motivate components of a standard
- Attitudes and abilities acquisition
- Update of contents. University-company relationship
- Standard applicability. Work world relationship
- Relationship with other knowledge areas. Application of the Geometric Product Specification (GPS) philosophy [8]

will establish different bases to carrier out didactic material.

The content of the standardized supplement is developed in a different way if an individual element or set of elements are tried. Two actions are considered in the development of the didactic material so that students can adopts a more active role, which helps them to analyze, synthesize and think in an individual and collective way:

- Elements should be presented dimensionally justified, taking into account design and manufacturing requirements, according to their functional requirements. Functional requirements can be utilized as a guidance to develop a part of standard supplement used as a didactic material.
- Auxiliary systems should be presented to study their function inside the engine set. Therefore, the elaboration of maintenance guide to show possible cause of mistake, from the analysis of element's state, is proposed.

C. *Competences*

The adaptation of the standardization to technical educations takes into account academic competences that should be acquired. A protocol to show the adaptation process of the standard supplement is proposed in Fig. 2, where the relationship among academic competences and their professional activity is contemplated [9].

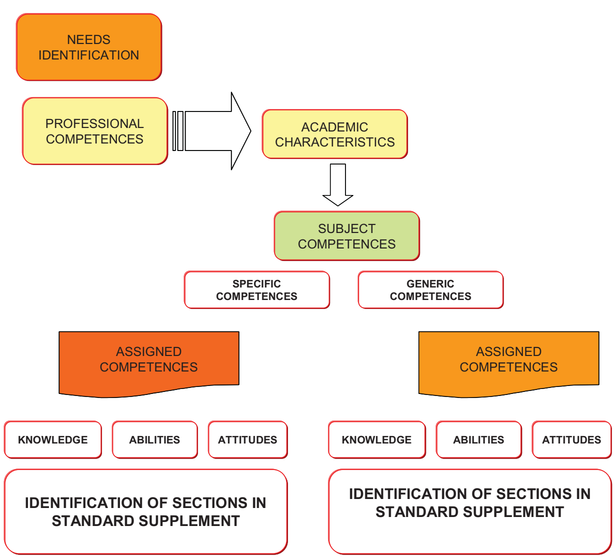

Figure 2. Competences protocol

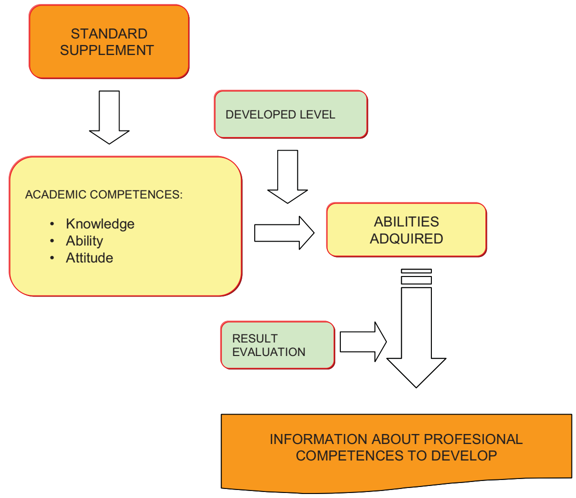

Figure 3. Standard supement generation

The protocol of competences and abilities is used to show a set of documents with a common guidance, which can be used as an aid material for the elaboration of a didactic material according to the capacities and professional necessities that should be acquired. The protocol, divided in two phases, includes:

- Phase I. Identification of society necessities
- Phase II. Development of competences that are implemented in standard supplement

As well, this work is only focused on the second phase.

Phase II contemplates the break down of knowledge, abilities and attitudes that standard supplements can give for established academic competences. These can be generic competences, common to the engineering, or specific competences, common to an engineering specialty.

The generated complexity level in the document should be taken into account, since the result of the acquired capacities should be according to the capacities established in professional competences (Fig. 3).

A matrix, for each of generic or specific competences, is elaborated to establish knowledge, abilities and attitudes [10, 11] that the document contributes and their level. This matrix is used to establish capacities that can be acquired and knowledge that are contributed for a certain competence. Structure of this information is shown in Table I.

TABLE I. STUCTURE OF MATRIX

SUBJECT:		**STANDARD SUPLEMENT:**		
Competence		***Action***	***Description***	***Level***
GENERIC				
SPECIFIC				

As an example, Fig. 4 shows a standard supplement proposed for an ICE connecting rod.

Some basic aspects of the model to be used in the development of standard supplements are considered:

- Clarification of objectives that should be reached. Academic competences are included in this document and they should be acquired.
- ˜Concepts representation. It is contrasted the importance that represents the incorporation of a high number of figures in the document.
- Document structure. The continuity of document has been considered as a disadvantage to structure it with different levels, having the possibility of a partial use (basic, middle and advanced levels).

Basic level includes the explanation of the elementary knowledge of the connecting rod-crank system, by means of the description of main parts of elements and their function. Finally, available applications for ICE are developed and justified.

Middle level presents the processes and materials used to carry out manufacture of the ICE connecting rod. A short description of employed systems is carried out, justifying their advantages and presenting main characteristics of used materials. A second part of this level develops functional requirements that have influence in the design and manufacture of element.

Finally, advanced level allows of determining the structural resistance of connecting rod, with a previous study of dynamic and kinematic system and forces.

The proposed objective is to establish and to put in order the content of standard supplement according to EHEA requirements and to give a pedagogical features, taking into account the document, which belongs to a standard.

The incorporation of EHEA requirements in each developed document depends on technical and functional characteristics of element. In this case, as it happens in other many ICE elements, functional requirements will be used to develop the knowledge that should be included.

The analysis of different functional requirements gives main and basic characteristics that the element must have. Once the element is characterized, a second analysis allows establishing operating conditions.

Dynamic and kinematic studies are used to determine efforts generated in connecting rod-crank system. Mechanical and structural calculations give the measured of necessary minimum sections.

The study of the element is closed by means of the selection of appropriate materials according to its functions, its solicitations and its manufacturing processes.

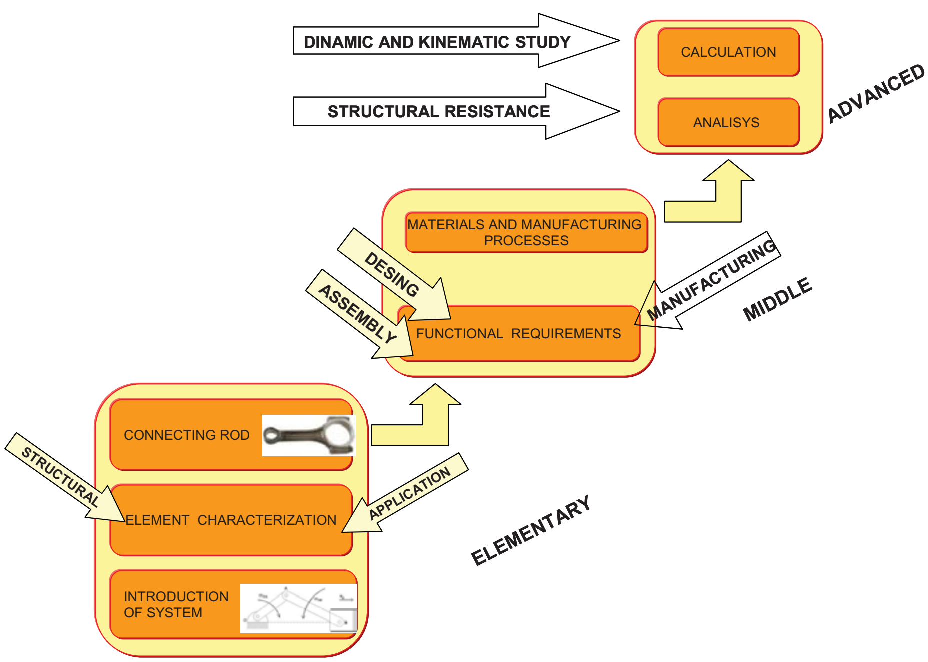

Figure 4. Application to a connecting rod

TABLE II. MATRIX OF COMPETENCES-ATTITUDES

SUBJECT:		**STANDARD SUPLEMENT:**		
Competence		***Action***	***Description***	***Level***
GENERIC	GC.01	Associate	Associating the system and his dynamic and kinematics variables to efforts that are produced in the element	Advanced
	GC.02	Associate	Associating efforts that are produced to the measured and structural calculation of the element	Advanced
	GC…	Compare Contrast	Comparing and to contrast the influence that dimensions of the system have on the set	Advanced
SPECIFIC	EC.01			
	EC.02			
	EC...			

The structure of standard supplement is corresponded with established complexity levels: basic, middle and advanced. However, these three levels do not reflected specifically, although if they are established, due to the continuity that the document should present.

III. CONCLUSIONS

Analysis carries out highlights the importance of standardization in the development of the professional activity, not considered widely in technical educations. Actually, the standard use and standardization field are low. It could be desired in engineering education a deep use, because of its high interest in technical learning. The incorporation of a standard supplement as didactic material can be used in the education so as to help and boost the use of standard documents.

It is necessary to develop a model to fill actual detected voids in some subjects. This development supposes the possibility to generate a non random model, equivalent to Geometric Product Specification philosophy, with a complete structured and coherent body for the ICE elements.

A protocol to evaluate the acquired academic competences has been elaborated. Its conversion to professional competences helps to determine the assimilation level of knowledge, abilities and attitudes. The elaborated protocol should include an evaluation performed by universities, oriented to the certification of academic responsibilities obtained, and an evaluation performed by employers, oriented for the certification of the professional responsibilities recognized.

The standardization can be used as a link between company and university technical educations. Responsible agents for the elaboration of a standard must stimulate existent communication channels, according to recommendation of EHEA.

The elaborated document show significant differences respect to conventional didactic material:

- Structure: standard supplement presents an additional value because of it is structured with different levels and allows to be applied to non university teachings, introducing advantages that standardization can give in other fields.
- Orientation to competences: the development of the oriented document to the acquirement of some academic competences, established in the moment of its elaboration, is useful to different agents on which the process has repercussions (students, graduates, academics and employers), being integrated their priorities in only one proposal.
- Integrative component: the integrative component that should present the elaboration of a standard can be taken into account so as to give the importance of involving the university and the industry as a base of its development.

ACKNOWLEDGMENT

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yPBL methodology: a problem-based learning method applied to Software Engineering

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ABSTRACT

This paper proposes the yPBL learning methodology, based on the well-known PBL method and adapted to software engineering process by using the "y" methodology. The yPBL methodology is defined as a mapping between the roles and phases considered in PBL methodologies to the roles, iterations and phases considered in the "y" methodology. Moreover, the yPBL method includes different situations of active and passive learning roles not only for the students involved in a course but also for the instructors. Indeed, software engineering instructors face the same challenge of any software engineer and needs to continuously update their knowledge in software technologies. The yPBL method has been designed using the Unified Modeling Language (UML) and the various interactions points between the various process actors as well as the information to be exchanged during the synchronous and asynchronous learning process have been specified using this language. Finally, interesting preliminary results of the experience of using this methodology in the INSA of Toulouse are included in this paper.

Keywords-software development process, problem based learning, unified modeling language, software engineering process

I. INTRODUCTION

Software engineering is a complex process demanding from development team members a high level of knowledge and experience in diverse areas going from project management skills to communication, design and implementation expertise. Moreover, the large diversity of software design and development approaches as well as the accelerated development of new software technologies requires a continuous learning process. This is not only the case for software engineers but also for academic instructors teaching software design and development courses.

Problem based learning (PBL) methods have been successfully used in different domains and its benefits have been largely demonstrated [1,2]. These methodologies ask for the active participation of the students within the learning process, playing not only the traditional passive learning role but also an active role where part of the knowledge needs to be discovered and applied by themselves. Moreover, the students may be asked to transmit the knowledge they have acquired to other students in order to reinforce the learning process as well as to demonstrate that the learning objectives have been achieved. Nevertheless, even if PBL methodologies have been designed to be easily adapted to any educational domain, the specificities of software engineering courses need to be carefully studied in order to improve the benefits of these learning methods while applying good practice approaches that are specific to this domain. As previously introduced, software engineering courses ask for multiple skills expertise acquisition and development. Indeed, students need to efficiently exert in the area of project planning, quality assurance, translation and traceability of customer requirements, analysis of the software context and constraints, mapping of functional and non-functional requirements to technical requirements, design of software solutions following good and well-known practices (e.g. design patterns or object oriented approaches), implementation of the designed solution, testing techniques, integration procedures and finally deployment and maintenance strategies of the software product and related documentation. The previous list is not exhaustive and shows the degree of complexity involved in designing PBL-based courses allowing students to play the required roles in order to achieve the software engineering learning objectives.

In the area of software engineering process, several methodologies have been proposed in order to efficiently support members of development teams to design and implement software products. Unified Process (UP) methodologies are very well known in the world of software engineering for providing an efficient process based on an incremental and iterative sequence of phases. Phases include analysis and specification of requirements, design and specification of the software solution and implementation, test, integration and deployment of the software product. These phases are planned and executed in incremental iterations where in each increment new customer requirements can be added within the process. Likewise, bugs detection and corrections as well as requirements change requests can be added in each iteration. As agreed in the software management plan, stable or experimental software products can be released at the end of the iterations.

UP methodologies have been specialized in the form of extended methodologies (i.e. Rational Unified Process, Enterprise Unified Process, Extreme Unified Process, Agile Unified Process, etc.). In recent years an interesting specialization known under the name of Two Tracks Unified Process (2TUP) has been proposed to face the reality of continuous changes of requirements and technologies that represents an invariant reality in software engineering. This methodology, also known as the "y" methodology due to its graphical representation, proposes a differentiation of 2 tracks for the Unified Process, the first (left) track represents the functional aspects of the software product and the second (right) track the technical aspects (e.g. technology, environment, platforms). This separation helps software engineers to concentrate on discovering and specifying the functional requirements that need to be satisfied (left track) while allowing them to explore and select the technologies that could be used to build the software solutions (right track). Once the functional and technical requirements have been identified and specified, both functional and technical tracks can be merged in order to produce the software design specification. From this point, the software product can be developed, tested, integrated and deployed. This sequence of parallel and serialized phases will be executed within the incremental and iterative process proposed by the UP method. Benefits of this interesting methodology have been demonstrated by its application in many industrial and research software projects.

This paper proposes a new learning methodology, based on the well-known PBL method and adapted to software engineering processes. This methodology called yPBL is aimed at being applied to develop software engineering courses within the context of real software projects. yPBL is defined as a mapping between the roles and phases considered in PBL methods into the roles, iterations and phases considered in the "y" process. The yPBL method defines a process where incremental and iterative phases and communication channels and deliverables are planned and defined to facilitate the interaction between external and internal actors involved in the real software project: "the client" and "the project team". Within the project team, students and instructors work together playing different roles in order to build the software solution required by the client. Guided by a real project, internal actors of the process are naturally involved in situations of passive and active learning. Indeed, similar to the students, software engineering instructors face the same challenge of any software engineer face to the accelerated software engineering evolution. For this reason, both instructors and students need to participate in a continuous learning process. The yPBL methodology also defines an internal process where the interactions between the internal actors are planned in incremental iterative asynchronous basis. In order to perform these interactions, internal actors need to work on learning activities including bibliographic research, course preparation and presentation and evaluation of peers based on real knowledge acquisition. Further in the software building process, internal actors need to apply their acquired knowledge in constructing the software solution. At the end of each planned iteration, interactions with the external actors (i.e. clients) are carried out in order to present and evaluate the product releases. During these interactions, the evaluation of the software product is done based on the client's satisfaction degree and the product qualities.

The yPBL method has been designed using the Unified Modeling Language (UML) and the various interactions points between the various process actors as well as the information to be exchanged during the learning, software construction and evaluation process have been specified using this language. The yPBL methodology has been successfully applied in several software engineering courses at the INSA of Toulouse.

The rest of this paper is organized as following. Section I presents a state of the art related to software engineering processes. Section II presents the yPBL methodology model. Section III describes a concrete study case illustrating the use of yPBL within a Software Oriented Architectures (SOA) course. Finally, several conclusions and perspectives of this work are presented.

II. State of the Art

In this chapter the state of the art aimed at providing the basis for the yPBL methodology is introduced. First section is aimed at presenting the main standards in software engineering processes. Second section briefly describes the 2TUP process that is the one promoted by the yPBL methodology. Finally, the main IEEE standards aimed at guiding and documenting software engineering process will also be presented.

A. Software engineering process

A software process defines the steps required to create a software product. One of the most mature and well-known software engineering processes is the Unified Software Development Process or USDP [3]. USDP was introduced as a standard process for creating software products based on the use of the *Unified Modeling Language* (UML).

USDP Introduces the concept of 4Ps: people, project, product and process. *People* working in a software development *project* collaborate within an adequate workflow based on the unified *process* using the common UML notation in order to build and represent the blueprint of the software *product*. The process includes all the activities needed to transform user's requirements into a software system. These activities include *project management, requirements specification, analysis, design, development and testing*.

USDP follows a *component-based approach*. This means that the software system being developed is based on software components interconnected via well-defined interfaces. Likewise, *object oriented design and development approaches* are followed within USDP.

There are three major characteristics differentiating USDP from other approaches:

- *Use-case driven*: the process is driven by the use cases or functionalities offered for each external actor (i.e. clients or any external entity interacting with the system). It means that the process does not consider functionalities that "might be good to have", but it is driven by the realistic usages of the system. In other words, use cases drive all the process phases: requirements, design, implementation and test.
- *Architecture centric*: during the process the software architecture is constantly refined including static and dynamic aspects of the system. It means that the form of the system is built progressively.
- *Iterative and incremental process*: the transformation of user's requirements into the software product is performed within an iterative and incremental process. During this process, the functions and the form of the system are represented by the use cases and the architecture respectively.

Various adaptations to the Unified Process (UP) have been proposed in the last years. These adaptations are based on the category of software system being developed, the organization involved, competence levels of development teams or the project size. Examples of these specializations are Rational Unified Process (RUP), Enterprise Unified Process (EUP), eXtreme Unified Process (XUP) or Agile Unified Process (AUP). However, most of the processes used today for designing and developing software systems are commonly based in the principles proposed by the USDP process. This is the case for the 2TUP process described in the next section.

B. *The "y" or 2TUP process*

As previously introduced, the Two Tracks Unified Process (2TUP) has been proposed to face the reality of the constant change of requirements and technologies of current software systems [4]. The "y" methodology proposes an iterative and incremental process composed by 2 parallels tracks aimed at capturing functional and technical requirements, followed by one centralized design track.

This tracks-oriented structure helps software engineers to concentrate on discovering and specifying the functional requirements that need to be satisfied (left track) while allowing them to explore and select the technologies that could be used to build the software solutions (right track). Once the functional and technical requirements have been identified and specified, both functional and technical tracks can be merged in order to produce the software design specification. From this point, the software product can be developed, tested, integrated and deployed. Further details of the "y" methodology will be presented in the next.

C. *Software engineering standards*

Several standards have been proposed in order to guide and document software engineering process. The most widely used in industry are the standards proposed by the IEEE:

- Software Project Management Plan (SPMP): specifies the structure of software project management plans that are applicable to any type or size of software project [5].
- Software Requirements Specification (SRS): specifies the structure and necessary qualities of software requirements specification documents [6].
- Software Design Description (SDD): proposes the necessary information content and recommendations for software design descriptions [7].
- Software Quality Assurance Plan (SQAP): specifies the format and content of software quality assurance plans [8].
- Software Configuration Management Plan (SCMP): describe the structure and content for a software configuration management applying to the entire life cycle of the software [9].
- Software Test Documentation (STD): this document defines the form of a set of documents for use in defined stages of software testing [10].
- Software Validation & Verification Plan (SVVP): specifies the structure of the validation and verification plan including analysis, evaluation, review, inspection, assessment, and testing of software products and processes [11].

These standards help to express and communicate in an unified way all the information related to the software process.

In the case of software engineering learning methodologies, the introduced software processes and related document standards, provide the basis to define a learning model where the learning objectives can be efficiently achieved while designing and developing a real software project. Next chapter introduces this software engineering learning model.

III. YPBL MODEL

The yPBL is a learning methodology, based on the PBL model and inspired in software engineering processes. As previously introduced, yPBL is aimed at being deployed in the context of software engineering courses based on the construction of a real software system. The yPBL model is defined as a mapping between the roles and phases considered in PBL methods into the roles, iterations and phases considered in the "y" process. As an intent to formally describe the yPBL methodology, the UML language has been used to build an yPBL model.

1) *yPBL use cases*

In order to follow the good practices for software engineering introduced in the previous chapter, the unified process has been used to model the yPBL methodology itself. As any unified process, the yPBL methodology is use-case driven as illustrated in Figure 1.

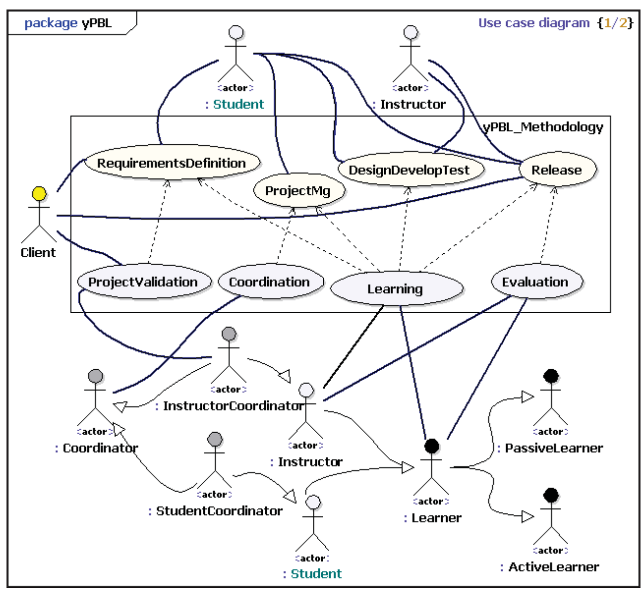

Figure 1. yPBL methodology use cases diagram

In this diagram the various actors interacting in order to achieve the learning objectives while constructing a software system are depicted: students, instructors and the external client.

Guided by the construction of the software project, two generalizations of actor roles are proposed in yPBL: coordinators and learners. The coordinator role is involved in the learning project management and the learner in the learning activities.

Specializations of the coordinator role are represented by instructor coordinator and student coordinator roles. These actors play a supporting role for activities such as planning, scheduling, hardware and software resources allocation. They monitor and control the project in order to early detect potential problems and work together to find efficient solutions. Specifically, the instructor coordinator actor is the one interacting with the external client in order to study and validate the project to be used to instantiate the methodology.

Generalizations of the learner role are defined by passive and active learners roles. Students and instructors play these learner roles. Actually, they are internal actors of the real process and as a consequence they are naturally involved in situations of passive and active learning face to the requirements for learning and applying software engineering technologies. Active and passive learning roles facilitate both instructors and students participating in the continuous learning process.

2) yPBL high level process

The yPBL method follows also the incremental and iterative process proposed by the Unified Process as illustrated in the activity diagram presented in Figure 2.

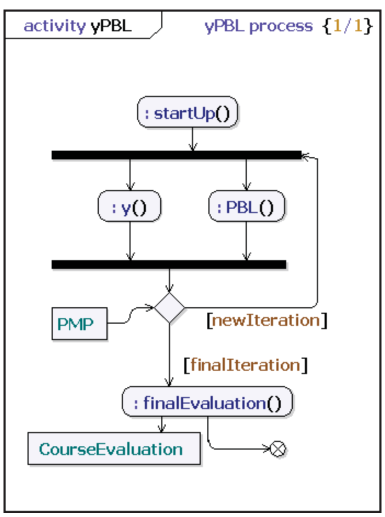

Figure 2. Process proposed by the yPBL

At the high-level yPBL process, an initial start up activity needs to be performed in order to prepare and validate the overall software-learning project. Once the start up activity is achieved, two parallel processes represented by the y and the PBL process are performed. The y process itself concentrates in software engineering activities. The PBL process targets the learning activities. During the overall yPBL process, specific adaptations to the standards presented in the previous section and proposed to guide a software project will be used to drive both y and PBL processes. The first standard is the Project Management Plan (PMP). This document is an adaptation of [5], [8] and [9] documents, and it is intended to control and manage the yPBL process. As illustrated in Figure 2, the PMP document is used for each iteration in order to control the project progress according the initial plan as well as to manage people, resources and deliverables involved in each phase for both software and learning project processes. Once the final iteration has been achieved, a final evaluation of the yPBL project will be performed. During this evaluation both learners participants as well as the learning process itself are evaluated. Results of these evaluations are reported in the "Course Evaluation" deliverable.

3) yPBL detailed level process

The various activities illustrated in the yPBL process presented in the previous section will be further detailed in this section. Specifications used to model internal yPBL activities are intended to describe the workflow process. In these specifications sequence of activates, interaction between the various process actors, as well as communication channels are specified.

Figure 3 illustrates the start up activity. This initial activity is performed as an interaction between the client and the instructor-coordinator.

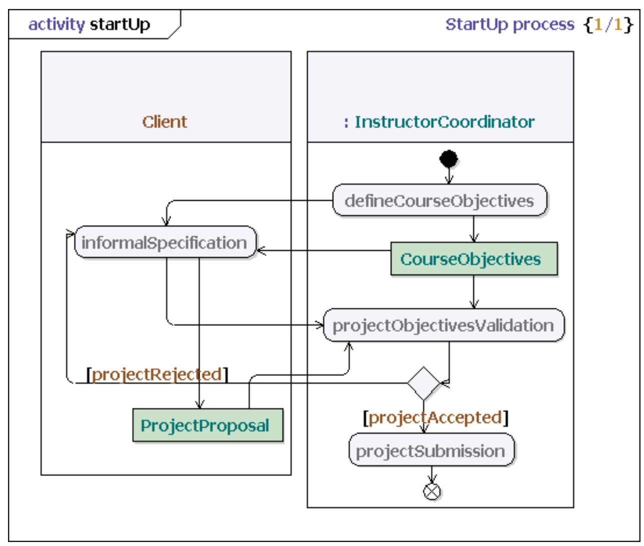

Figure 3. Starting up process

The start up activity starts when the instructor-coordinator defines the course objectives from the functional and technical point of view. Functional objectives are defined as abstract learning statements aimed at expressing the basic and fundamental knowledge goals to be acquired by the learners. Technological learning objectives are intended to express concrete statements based on current software technologies to be used by the learners in order to apply the basic knowledge goals defined by the functional objectives. The document called “Course Objectives” is used to collect these functional and technical objective specifications. This document is communicated to potential clients in order to allow them to propose an objective-compliant project. Clients are asked to propose an informal specification of the project in the form of a “Project Proposal” that will be validated or rejected by the instructor-coordinator. If the project is accepted it will be submitted to the rest of the yPBL process actors.

From this point and as illustrated by the high level yPBL process in Figure 2, two parallel processes guiding the software and learning project activities are started. Figure 4 illustrates the activity diagram modeling the software project process. Students and instructors perform collaborative or individual activities for every iteration of the y process. In order to stimulate autonomy skills, students are asked to work on the functional and technical analysis phase of the project based on the “Project Proposal” submitted by the client. During this phase, students need to interact with the client in order to clearly specify and validate the software requirements and produce the SRS document [6]. Likewise, students are asked to work on the PMP document in order to define the plan to be executed within the several process iterations. Furthermore, they are also asked to pay special attention in defining a realistic project plan based on the priorities of the requirements expressed by the client.

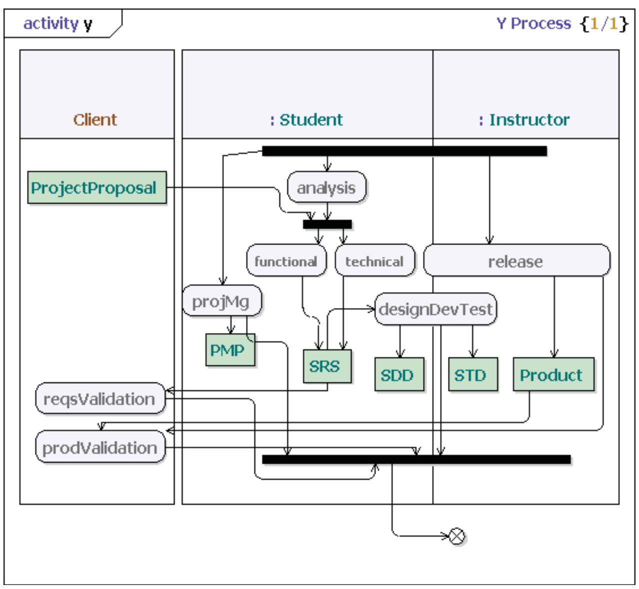

Figure 4. 2TUP or y process

During the design, development and testing activities, both students and instructors work together in order to produce the artifacts expected to be released in every iteration. In these activities the role of the instructor is clearly separated from the client role and this is one important benefit offered by the yPBL method. Indeed, the instructor plays a supporting role intended to help the students to achieve the software project objectives. During these activities, design and test oriented documents are produced following the SDD [7] and STD standards [10]. Following the PMP plan and before the end of the iteration, specific interactions need to be performed with the client in order to validate the “Product” release against the software requirements expressed in the SRS.

In parallel to the y process, learning activities guided by the “Course Objectives” are being carried out for every iteration. Figure 5 depicts the activities performed by the coordinators, instructors and learners during the PBL process.

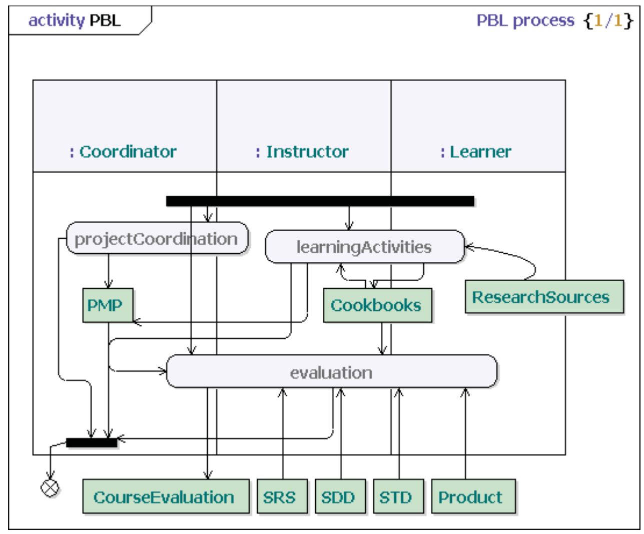

Figure 5. PBL process

Actors performing the role of coordinator (i.e. instructor-coordinators or student-coordinators) perform project coordination activities for every iteration. They work on the PMP document in order to facilitate the project progress and anticipate actions aimed at minimizing potential risks. Coordinators work together on the basis of periodic meetings or by email communication. During these interactions, coordinators exchange monitoring information collected during the process. This information can be used to encourage positive experiences and good practices as well as to work together in solutions to solve detected anomalies.

Likewise, instructors and learners work together in learning activities, which are naturally deduced from the plan, defined in the PMP. Indeed, as the project has been validated based on the learning objectives, the learning activities to be carried out in order to construct the software project can be directly deduced from the PMP. This is particularly important to guarantee the rationalization of the learning objectives and this is another important benefit offered by the yPBL methodology. Students and instructors work together to define and plan learning activities to be carried out in every iteration of the process. In order to efficiently carry out these learning activities accordingly with the plan, both actors need to participate in the research and preparation of the learning material. Instructors work together on the definition of a list of learning subjects. These subjects will be prepared and presented by both students and instructors. In order to facilitate the preparation of the learning material, bibliographic "Research Resources" need to be identified and proposed by both actors. In order to guarantee that the learning material to be produced is compliant with the plan, resources and project requirements, an approach based on the elaboration of "Cookbooks" can be followed. "Cookbooks" are aimed at proposing an efficient presentation of definitions and concepts (i.e. the ingredients), and how they can be applied to construct a particular software function or service (i.e. the recipes). Recommended resources and links are also proposed in the cookbook. Instructors and students carry out the preparation of the cookbooks and specific timeslots are reserved to allow them to present these learning materials. The cookbooks are also stored in a common repository in order to facilitate its access during the project process.

This is another benefit offered by the yPBL methodology. Indeed, internal actors play the roles of active and passive learners, working individually or within groups in learning activities including bibliographic research, course preparation and presentation. Moreover, the evaluation of these activities is carried out by the peers based on the real knowledge acquisition. Furthermore, during the software building process, internal actors need to apply their acquired knowledge in constructing the real software solution.

Finally, for every PBL iteration the evaluations is carried out based on the SRS, SDD and STD documents. From these documents the achievements can be objectively measured based on the requirements identification, solution design and implementation, and the test performed on the final product. Results of the evaluation in every iteration are stored in the "Course Evaluation" document.

The last activity considered in the yPBL process is the final evaluation. This final evaluation activity is carried out after the last process iteration. During this activity, all the process actors are asked to participate in a final project presentation including the final version of the project documents as well as the delivery of the final release of the project. During this activity, the functional and technical project requirements are finally measured, as well as the global satisfaction of the internal and external actors. The process itself is discussed and a list of suggestions and remarks are compiled and included in the "Course Evaluation" document. This information is very helpful to improve the process for future projects and also to measure and compare the final results.

IV. STUDY CASE

The yPBL methodology has been designed based on the experimental results obtained by applying PBL methodologies for software engineering projects in the INSA at Toulouse in France. During the last 2 years, the yPBL methodology has been experimentally used with students of 4th and 5th year of software engineering. These courses can be classified in two categories: introductory design and development courses and advanced technology oriented courses. For both categories of courses, the yPBL has been successfully followed.

In order to propose a friendly interface following the methodology, a template course has been defined using the Moodle learning management system [12]. This template is illustrated in the Figure 6.

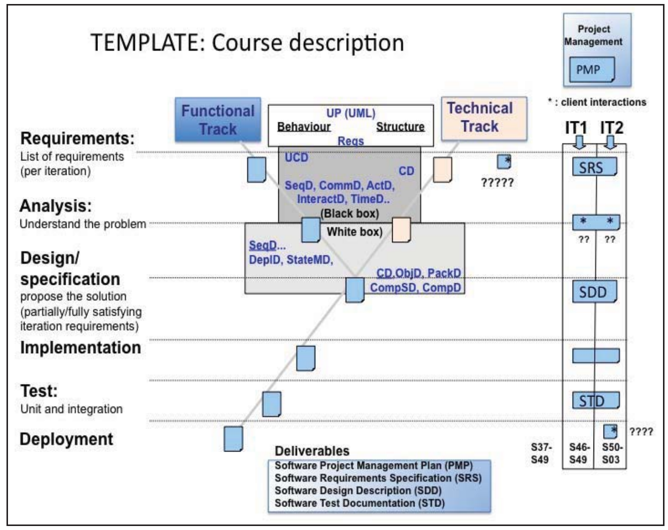

Figure 6. yBPL template for moodle interface

This template is used in order to facilitate the interaction between the various actors of the process. The interface illustrates the "y" software project methodology with the functional and technical tracks including the requirements and analysis phases as well as the merging central track aimed at designing, implementing, testing and deployments phases. For every track and iteration, explicit indications of document deliverables links are included (PMP, SRS, SDD and STD). Likewise, links to the documents produced during the learning process in the form of cookbooks are also included in the interface. This interface is configured during the start up process, and the "Course Objectives" and "Project Proposal" documents are also included. The interface is adapted to the various project and learning process actors in order to facilitate their collaboration during the whole process.

In order to illustrate a real instantiation of the methodology, a concrete study case based on a Software Oriented Architectures (SOA) systems course will be presented. Details of this study case are presented in the Table 1.

Actor	Description
Client	Direction of the DGEI-INSA department
Instructors	4 Software engineering instructors 6 Software oriented architectures instructors 3 English instructors
Students	60 students of the 5th year of IT and Networking engineering
Coordinators	1 instructor and 5 students
Learners (A/P)	5 instructors and 60 students

Table 1. Actors participating in the SOA course

The client proposing the project is represented by the GEI department of the INSA. The project proposed by the client asks for a system able to automate financial accounting activities. In the process a number important of users, interface and data needs to be considered to build the system.

The instructors participating in this course are divided in 3 groups: software engineering, SOA and English instructors. The first group of instructors targets the software engineering process and the second group targets the software technologies to be used to design and develop the software solution. English teachers participate actively in the project, working with the students in the elaboration of the documents in English versions. Moreover, English teachers supervise and guide the students in activities aimed at writing and presenting the various cookbooks developed during the learning activities and related to the project software requirements. The students participating in the project are divided in two categories: IT and Networking engineering students. Students work in groups of 12 students and each group can work in a different sub-system of the global project. The group of coordinators is composed of 1 instructor and 5 students, one student-coordinator for each groupe of 12 students. Finally, the learners groups are composed of all the students and 5 instructors mainly working in the area of software technologies.

The objective and subjective measurement results obtained from the application of the yPBL methodologies have been highly motivating. Indeed, instructors and students consider as very positive the gained experience from working in a real software project. Moreover, instructors remark the high motivation of the students, particularly when they perform learning and teaching activities. Furthermore, even if at the end of the project the full set of clients requirements have not been satisfied, students are able to explain the reasons for this partial result. They claim to have understood that living the process is the best way to know how to do things working and how to avoid in the future making the same mistakes.

Conclusions and Perspectives

This paper has presented an innovating learning methodology, based on the well-known PBL method and inspired and adapted to software engineering unified processes. The yPBL model describing the use cases driving the methodology as well as the various internal activities guiding the process has been presented. This model has specified the relationship between the roles and phases considered in PBL methods and the roles, iterations and phases considered in the Two Tracks Unified Process (2TUP) or "y" methodology. The yPBL methodology has been defined as a process where incremental and iterative phases are performed and specific communication channels are established by the way of standard documents in the framework of a real software project. A case study illustrating how this methodology has been instantiated at the INSA of Toulouse has also been presented. Motivating results have been obtained during the experimental application of the yPBL. At the moment of writing this paper, a new instantiation of the methodology has been started and a more important set of measurements will be performed in order to better analyze and evaluate the benefits offered by yPBL.

Acknowledgment

The yPBL methodology has been successfully designed, implemented and experimented thanks to the valuable and active participation and collaboration of the GEI and CSH departments at the INSA of Toulouse, including direction, administration staffs as well as the teachers and the students participating in this project.

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[9] SCMP: Software Configuration Management Plan IEEE 828

[10] STD: Software Test Documentation IEEE 829

[11] SVVP: Software Validation & Verification Plan IEEE 1012

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Session 11B Area 3: General Issues in Engineering Education - Theories and studies about learning layouts

A Systems Theory Perspective of Electronics in Engineering Education

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Implementing new learning methodologies in the Hard Sciences: a cross curricular study of students' and professors acceptance

Amante-García, Beatriz; Oliver, Sonia; Ponsa, Pere; Romero, Carmen; Vilanova, Ramón

Autonoma University of Barcelona (Spain); Autonoma University of Barcelona (Spain); Technical University of Catalonia-UPC (Spain); Technical University of Catalonia-UPC (Spain); UEM (Spain)

Attracting, Retaining, and Preparing a Diverse Academic Engineering Workforce

Donnelly, Anne; Jacobi, Jane
Clemson University (United States of America); University of Florida (United States of America)

A Systems Theory Perspective of Electronics in Engineering Education

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Abstract— **We briefly review fundamental concepts related to systems theory and systems engineering. We also review and structure a list of important properties for an electronic system and paradigms and techniques applicable to analysis and design. Then we present two specific case studies, in which the systems theory approach to electronics engineering teaching and research has been very influential.**

Keywords: ***systems theory; systems engineering; electronics systems engineering; model-based systems engineering; requirements; requirement-driven engineering; validation; verification; systems engineering education; electronics engineering education***

I. INTRODUCTION

Systems theory is an interdisciplinary and holistic approach to the study of complex structures and behaviors [1]. This theory is the main foundation of systems engineering, which on the one hand, is evolving as a specialized professional and academic discipline and, on the other hand, permeates other disciplines as a process and methodology. We present here a perspective of electronics engineering education and research from the systems theory and systems engineering approach.

We can identify two extreme approaches to systems engineering. The top-down approach followed by the professional who acts in the role of a pure systems engineer, without attachment to any specialized branch of engineering or technology; and the bottom-up of the specialist moving to a more general and system-level perspective. Both have advantages and disadvantages. One can argue that pure systems engineering specialization lacks a knowledge of details and of real capabilities of technology and solutions, and that the devil is in the details. The danger of the second is not seeing the forest for the trees. Here we propose a zooming approach to electronics systems engineering, shifting from the micro to the macro view and vice versa, as appropriate, and pointing out relationships, general properties and how they depend on decisions taken at every level. In reality, this process is applied in science when dealing with complex analysis or design issues, such as in medicine, where it is common to combine the microanalysis with the physiological, anatomical and environmental view in studies and diagnoses.

After this introduction we first present a summary of the process typically applied in systems engineering, consisting of iteration between requirement analysis, functional design and synthesis, with verification between steps, iteration, top-down decomposition, and validation of results against the perceived need and objectives.

Then we deal with enumeration and classification of the properties to be taken into account in an electronics system, as a basis for requirement analysis, and the applicable design and verification methods. The identification and structuring of requirements and properties is one of the open problems in systems engineering and, although theory and methodologies have been proposed, it relies mostly on the open-mindedness and creativity of the analyst.

Then we continue with the presentation of two case studies in which the systems perspective has contributed to a differential approach to electronics engineering education and research. We end with conclusions and proposals for future work.

Electronics systems are now prevalent in every field of human activity. They are often complex, with many interfaces and relationships. Failure of one of those systems can result in economic damage and even loss of human life. We think, therefore, that it is relevant to propose an integral and system-level approach to electronics systems engineering. That approach should also be incorporated in research and education, conveying ideas, perspectives and techniques to future professionals.

II. SYSTEMS ENGINEERING

Systems engineering can be considered as a methodology or discipline in itself. Globe-spanning professional organizations such as INCOSE (National Council on Systems Engineering) and the IEEE Systems Council (a council formed by several IEEE societies) are promoting research, practice improvement and education in systems engineering.

A. Systems Engineering process

An objective and differential characteristic of systems engineering is the exploration of alternatives and early adoption of critical design decisions. Several process schemas for systems engineering have been proposed, such as the SIMILAR, by INCOSE [2]

We include here a simplified three-phase process (Fig. 1). This schema has to be run in iterative phases, verifying functionality against requirements, on the one hand, and design against functionality on the other. It is also applied in a hierarchical fashion following a top-down spatial decomposition of requirements, functionality and structure and applying the same cycle to every subsystem, module or component. This process has been assimilated to fractal geometry, with repetition of the process at different scales and not totally deterministic growth [3]. The results of the application are validated against perceived needs and objectives.

The main phases of the process can be summarized as follows:

- Identification, classification and contrast of requirements. A coherent, non-ambiguous and feasible set of requirements must be generated. Requirement definition is always a balance between capabilities and needs. This is a crucial step, as requirements provide the basis for performing all other key development activities such as system and component design, implementation, and testing.
- Functional design and behavior modeling. In this step it is important to think more about abstract functions that the system should perform, than about specific implementations. Functionality should be verified against requirements.
- Structural design, alternative selection, synthesis. Here, components, technologies and architectures are chosen to implement the functionality. The design has to be verified against functionality and behavior.

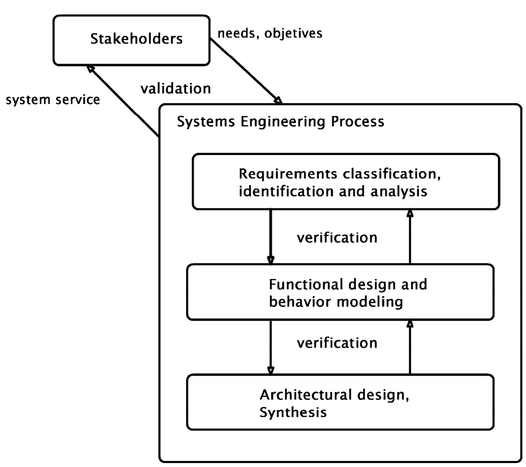

Figure 1. Systems engineering process

Model based systems engineering (MBSE) uses formal methods for modeling and analysis during the requirements, design, analysis and verification phases. A language oriented towards the modeling of complex systems and born as a subset of UML (Unified Modeling Language), with extensions, is SysML [5]. SysML includes diagrams for requirement, structure and behavior modeling, some of them common to UML.

B. Properties and requirements

A "well-formed" requirement is a constraint imposed on a property of the system. In order to establish requirements, it is necessary to first consider all relevant properties of the system. It is usual in electronics engineering to take into account properties close to the technology, such as time and frequency response, maximum ratings, etc. The systems engineering approach implies that more general properties or characteristics should be considered when analyzing requirements. We try to convey a structured list of those we have found important in electronics systems analysis and design:

- Involving system dependability, that is, the confidence that the system will provide the intended service [6]: availability, safety, integrity, maintainability, confidentiality, etc.
- Involving the ease with which the system can be used, reconfigured, tested or debugged: usability, manageability, adaptability, modularity [10][11], composability [7][8], testability, traceability, etc.
- Involving predictability in the execution of the intended functionality: input-output response (value and time), determinism, operating modes, graceful degradation, etc.
- Involving energy, power, and compatibility with the environment: power feeding, power efficiency, power and thermal management, power density, electromagnetic compatibility (EMC), etc.
- Economics: overall life cycle cost, cost of ownership, return on investment (ROI) , etc.
- …

In the design, which can include hardware, software, communications, sensors, actuators, and so on, the application of some paradigms and techniques can be considered, such as:

- Partitioning and distribution of functions, redundancy, replica determinism [9][42], etc.
- Distributed control and management, fault tolerance, real time scheduling, concurrency, etc.
- Computational models, hard-soft decomposition, programming paradigms, etc.
- …

Rigorous specification, verification and validation could demand the application of formal methods, modeling and simulation languages [4], RMA (reliability, maintainability, availability) analysis, etc.

Modeling and simulation is the preferred verification method before physical design. Electronics engineers have traditionally made use of simulation and modeling tools, based on hardware description languages (SPICE, VHDL, VHDL-AMS or Verilog) and even, more recently, hardware-software codesign-oriented languages (such as SystemC). Tools capable of multi-domain continuous, discrete and hybrid system simulation and modeling are very valuable for systems in which electronics is combined with other technologies. Modeling and simulation based on other computation models, such as the discrete event or finite state machines, are also often necessary.

III. Case study I. A Postgraduate course in modelling and control of inverters

Inverters or DC-AC power converters are widely used in uninterrupted power systems [19], renewable energy integration and distributed generation [41]. The expansion of renewable energy in the last few decades has heightened interest in inverter control techniques, both as autonomous generators (in a UPS, for example) and as a feeder connected to the electrical grid (in a PV solar farm, for example)

We try to describe here how the systems approach has influenced our research and teaching in this specific area. More specifically, what the impact has been on a recent proposal for a short postgraduate course in inverter modeling and control. It is not an objective to describe the proposal itself, but only to explain how systems theory, and systems engineering, has influenced its approach and development. Most of the decisions and orientations were adopted as a result of the requirements analysis phase.

Considerations related to high availability, a fundamental requirement for UPS, had an important influence. High availability means that redundancy has to be applied, which drove us to consider aspects related to modular decomposition. In fact, most modern UPS are modular, based on a set of easily replaceable modules working in parallel. A modular architecture brings additional advantages such as flexibility in expansion, adding power as needs evolve.

Paralleling modules implies that they must work in tight synchronization and share load. Parallel inverter control has been and continues to be a subject of constant research [12][13][14][15][16]. We are dealing with this problem as part of a study in the distributed, fault-tolerant, real-time control of modular electronics systems.

The combination of modular power converters can be approached from a more general point of view, with application of bond graph modeling techniques [18] (Fig. 2). This approach emphasizes analogies between different types of power converters, such as an inverter or a controlled motor. It is a typical example of the generalization process applied in systems theory.

When an inverter works as an autonomous generator, the analysis cannot disregard one of the most important requirements: disturbance rejection capability (Fig. 3) , or the ability to maintain wave quality under distorting or varying load. That is, low total harmonic distortion (THD). UPS applicable standards impose limits and establish test procedures [20]. This requirement had a decisive influence in the selection of the modeling and control techniques applied.

We propose a model for a controlled inverter that establishes a clear distinction between modulation and control (Fig. 4). This is a typical decomposition result of the application of a functional analysis phase. Pulse width modulation, or space vector modulation for a three-phase inverter, is studied independently of control [21]. The modulator only affects control through the actuation delay, which it can add to the loop, especially when regular modulation is applied [22].

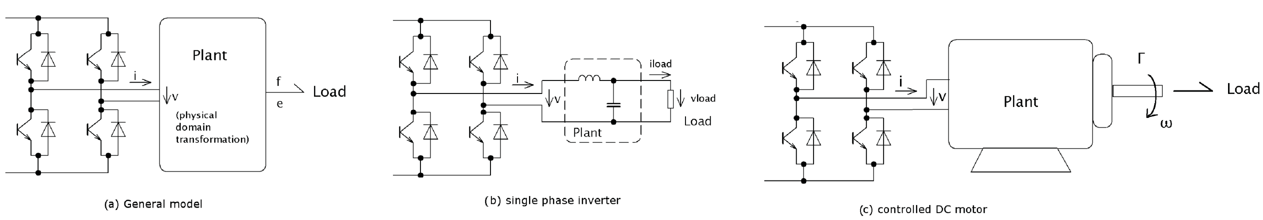

Figure 2. Bond graph models: generic, inverter and controlled motor

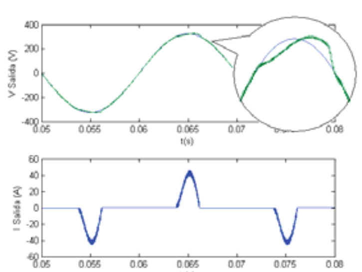

Figure 3. Inverter output under distorting load

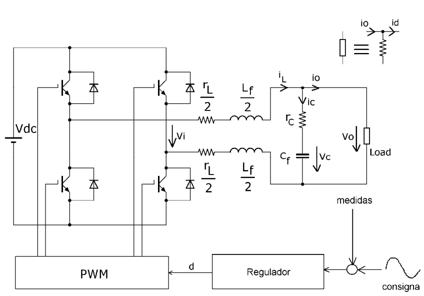

Figure 4. Single phase inverter model

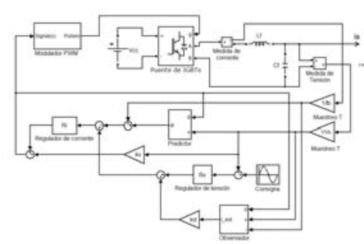

Figure 5. Digital controller model

The control technique applied determines set point following and disturbance rejection capacity, that is, output impedance [23][29]. We propose continuous and discretized state space models of the controlled inverter, which are then used as a basis for controller design [25][26]. Even the design of the controlled plant itself (the LC output filter [24]) is based on control requirements. We signal the importance of current control, in an internal loop, to yield quick dynamics and good disturbance rejection capability.

In a typical application of MBSE concepts, we decide to propose a reference controller, with the best possible performance: of continuous type, based on feed forward of output current, natural modulation etc. Against this reference controller others are contrasted and evaluated, such as digital controllers (Fig. 5) that can be implemented over microcontrollers or digital signal processors [17], and based on predictive current control and output current observer [27][28][29][30][31][32][33][34][35].

As a modeling, simulation and analysis tool we use the Matlab-Simulink suite, R2008b version, applying the Control System and Symbolic Math toolboxes, and the SimPowerSystems Blockset.

An exhaustive analysis of control requirements drove us towards the need of taking into account control related aspects such as reference sine wave generation. Synchronization of this reference with other modules or with the grid should be taken into account, and the applicable techniques studied [36][37]. The load sharing problem, with synchronization and without degradation of availability, motivated the research of classical techniques, such as the droop method, and other possibilities based on communication between modules and replica determinism.

A broad consideration of inverter applications includes the consideration of its integration in different kinds of electrical grids, in grid-feeding, grid-creation or grid-support mode [38][40] (Fig. 6). The modeling, simulation and control techniques are completely different from those applied for the inverter itself. We model the inverter as a voltage or current source and apply time-varying phasor modeling techniques [39].

The "zoom" view previously mentioned is applied in the lectures. The different control time scales, from the internal to that applied in grid integration, are contrasted. In the requirement, functionality and architecture analysis of the internal inverter, characteristics are associated with integration of inverters in modular systems on in electrical grids or microgrids.

IV. CASE STUDY II. TEACHING ELECRONICS IN A SECOND CYCLE CURRICULUM IN INDUSTRIAL ORGANIZATION.

In 2001 J.Q. started teaching Industrial Electronics as a subject in a second cycle curriculum in industrial organization, at the University of the Basque Country (UPV-EHU), Spain. The subject involves 30 lecture hours and an additional 15 laboratory hours. In a trimester, general, analog, digital and power electronics have to be taught to non-specialist graduate students, most of whom have no previous exposure to electronics. The course is geared toward graduate students with a technical engineering degree in chemistry, computer science or mechanics, for example. The most important concern was having a syllabus that was too scattered and blurred, difficult to understand and assimilate, in the short period allocated to the subject.

The syllabus was gradually refined over each of the several courses taught, and is now divided as follows:

- Introduction to industrial electronics: review of electrical circuits, basics of semiconductors, P-N junction, devices (BJT, MOSFET, Thyristor, IGBT). The different physical scales and ranges of application are reviewed, form micro-integration to power discrete devices (6 h. approx.).
- Analog electronics. A general and abstract approach is used to review the most relevant properties, characteristics and requirements: gain, feedback, linearity, frequency response, differential amplification and common mode rejection. At a more concrete level the operational amplifier and the most basic circuits are presented (4 h. approx.).
- Digital electronics. We review the basics of digital electronics, and then schematize combinational and sequential digital systems, paying special attention to fundamentals and examples of specific circuits. The objective is to give the students the foundation to understand the basics of microprocessors. Then we use a simple microcontroller model to convey the principles of programmable digital systems, including input-output and digital to analog and analog to digital conversion (8 h).
- Power electronics. A generic and abstract model of a power converter, including control, is presented. Specific models, such as diode rectifiers, thyristor controlled rectifiers, and switching DC-DC and DC-AC converters are briefly studied. We note differences and analogies in control and highlight basic concepts such as static and dynamic losses, efficiency etc. (8 h).

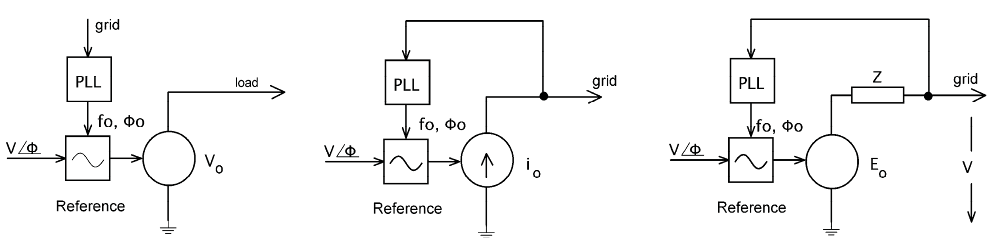

Figure 6. Grid forming, grid feeding and grid supporting inverters

Laboratory classes are partly devoted to practice with circuits and instrumentation, and partly to exercises and discussions. At the end of the trimester we study a relevant integral example. The few students with a previous background in electronics collaborate in the proposal and development of the example. The "zoom" technique is applied here to review characteristics, and the basics of the systems engineering approach are used to study requirements and associated functionality. Some examples of systems: a PV solar farm, a multiple lift system for an intelligent building, automotive electronics etc. (4 h)

We constantly strive to keep the system view in mind, using analogies to medicine and the human body: cells and tissues for devices, senses for analog electronics, the brain and nervous system for digital electronics and the locomotor system for power electronics. And we prioritize the requirement and functional analysis over implementation, although implementation limitations are taken into account to illustrate the need for a feasible requirement proposal for the systems.

Grading is fundamentally based on a final exam, based on questions and very short exercises. The overall experience has been very positive; more than 300 students have attended the course since 2001 with high average results and positive feedback in student opinion polls.

V. CONCLUSIONS AND FUTURE WORK

Modern electronics engineering has to deal with complex and critical projects and ample diversity of techniques and technologies [42]. Complex requirements have to be met, time to market reduced, and it is necessary to deal with limited budgets and design to cost constraints. Electronic systems must often be assembled from COTS (Commercial Off The Shelf) electronic subsystems and components, which may be manufactured half way around the world, and for which the most important task is to prescribe and verify characteristics against requirements. The systemic approach is a powerful tool to tackle with these demanding challenges. We think it should be included in academic curricula and applied in research and education.

Future research will focus on analyzing the possibility of using Case Study I as the basis for developing an educational example of MBSE, with application of the SysML language and perhaps other modelling tools, following a detailed systems engineering process.

Case study II can be the basis for the proposal to include a systems engineering subject in curricula [43]. INCOSE maintains a directory of systems engineering academic programs[44]. There are no Spanish programs included in the directory as of the writing of this paper.

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J. Q. has maintained fruitful and interesting discussions in systems engineering related forums and wished to thank all of the professionals involved in those discussions.

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Implementing new learning methodologies in the Hard Sciences

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Abstract— **Today's society is undergoing constant changes and this is reflected in the way the working world is structured. There is an increasing need of qualified professionals having to face changes and prove effective competencies dealing with the Information and Communication Technologies (ICTs).**
In this sense, the 21st Century university should offer students the suitable learning tools to become successful professionals. With this goal in mind the Tunning Project aims at implementing active methodologies by enhancing content learning and competencies acquisition.
In this paper, we include a comparative study of the efficiency of new learning methodologies across subjects, degrees and academic cycles and focus on the role of the ICTs in the learning process. Our objective is to assess the suitability of these new methodologies for technical subjects. Finally, we present a survey on professors' willingness to implement active methodologies.

Keywords-New learning methodologies implementation, continuous evaluation, students' satisfaction, competences and quality.

I. INTRODUCTION

Nowadays changes in society are being reflected in the working world. Likewise, the education area should be undergoing such dynamic pattern. Our globalized world demands really high qualified professionals able to face challenges and, at the same time, master key competencies and prove efficient skills in ICTs [1,2]. As a matter of fact, our 21 st Century University should train students to become autonomous learners and citizens able to cope with a constant changing working world.

Among other challenges, university students have to deal with a huge amount of knowledge just generated in the last few years [3], in this sense, their training should aim at enhancing self-learning ("learning to learn") besides from acquiring core contents, which will eventually become obsolete [4].

Therefore, universities should change their focus onto a more competencies-based view providing, then, future professionals with abilities [5, 6, 7] and habits that allow them to keep on learning throughout their professional careers. Definitely, ICTs can help achieving this lifelong learning goal as many recent studies have shown, among others, [1,2], within the Engineering field.

On the other hand, self-learning [4] is one of the most valued skills to succeed professionally.

In order to reach such an autonomous learning and master specific and inter disciplinary competencies (following the Tunning Project [8]) it is necessary to implement active methodologies in the subjects as through these new tools both professors and students can work on the subjects contents and competencies simultaneously. Not to mention, the key role ICTs play in this recent learning process model.

In this sense, the Polytechnic European University of Madrid and the Polytechnic University of Catalonia (EISEIAT) among others, are changing the scope of several University studies, such as Environmental Sciences or Telecom and Industrial Engineering to suit the European Higher Education Area (EHEA). As to the curricula, we have to mention that the learning is always student-oriented and based on the competencies this profile of students should have after graduating. With this goal in mind, we have incorporated new teaching methodologies and the use of ICTs in our classrooms and labs. Precisely, some of the methodologies used are related to the Cooperative Learning (CL) [9, 10, 11, 12] and Problem/Project Based Learning (PBL) [13, 14, 15, 16, 17, 18, 19]. These two methodological approaches to both teaching and learning allow students to become responsible for their own learning, decision making and knowledge developing starting from their professors' guidance, activities planning and new learning scenarios.

So as to apply such methodologies a professor must reflect on the specific learning objectives and the selection or design of problems and/or activities by firstly identify the learning needs of these students in particular. Besides, this professor should be aware of all the subjects taught in the same degree and, therefore, coordinate with the other professors involved. [20]. We would like to emphasize that during the whole process professors should design a follow-up plan of their students' work and, at the same time, an individual and team assessment. [17, 18].

The work presented in this paper is, therefore, a comparative study of the efficiency of active learning (AL) methodologies implementation in a wide range of subjects from different degrees and cycles at University. Not to mention, in this article we also focus on the use of the ICTs as a key tool in the learning process.

With this study, we aim at assessing and validating these new methodologies and tools in terms of suitability for technical subjects with such varied contents as the ones chosen for this research. Among others, we selected subjects from Environmental Sciences, Telecom and Industrial Engineering from the European University of Madrid (UEM) and the Polytechnic University of Catalonia (UPC). Besides, we have also focused on the possible differences in efficiency of those methodologies depending on the university cycle the particular subjects belong to. [1, 6, 7, 14].

Finally, we include a preliminary study on professors' knowledge on new methodologies and an example of AL methodologies implementation in a university subject with a small group of students from the UPC.

II. OBJECTIVES

Being aware of the multiple variables to account for in these typology of studies, we will precise the ones taken into account at each stage. In the first part of this paper we will describe our experimentation at the Superior Technical School (ESP) of the UEM.

First, we will assess the implementation of an AL methodology (Cooperative Learning and/or Problem/Project Based Learning) in three subjects of the first academic year in the Environmental Sciences, Telecom and Industrial Engineering degrees. Secondly, we will focus on the differences in acceptance of these methodologies across cycles and degrees within the same Technical School.

Aiming at the assessment of these new methodologies in terms of contributing to the learning quality and, more precisely, in the preliminary experimentation carried out in the selected subjects and cycles we have carefully taken into account the following points:

1. The evolution of the marks obtained by students: by comparing the percentage of grades resulting from the AL methodology implementation in the subject with the results from previous academic years when a more traditional learning approach was taken. In addition, the comparison of students' results between subjects where active learning techniques are applied and those where not both across degrees and cycles. We should emphasize here that only the subjects taught by the same professor during different academic years and using varied methodologies have been considered.

2. The results obtained from the student's satisfaction surveys dealing with the implemented methodology and the assessment of the competencies enhancement.

3. The results from the student's questionnaires on their satisfaction with the teaching staff.

Moreover, throughout the different sections of this paper we will comment on several studies carried out by other universities and whose results are very similar to ours, therefore, validating our work on the implementation of new learning methodologies in the hard sciences [6, 7, 14, 21].

Finally, we will include some professors' assessment on knowledge development and their application views on new methodologies of teaching and/or learning as well as a detailed description of the activities used during the implementation of such tools in our study.

III. DESCRIPTION OF THE ACTIVITIES USED

So as to design a wide range of activities to apply in each and every one of the subjects in this study we developed a common grid [22]. In it we have included examples of the key points to be considered when designing CL or PBL activities. In [22, 9, 16, 17, 18], a careful description of some of the activities carried out in the different subjects (scope of this study) is provided as well as other activities applied in similar studies taking place in other universities. Each activity aims at enhancing a particular competence, as it would be the case of team work (typically used in CL or PBL), oral communication or planning

Some of the activities that we can find in the above mentioned articles are the following:

1.- Project management and planning learning. A team work of maximum 10 students guided by a professor [20]. MS Project is used in here as a tool to plan and follow-up a project. Moreover, the professor will be handed in a weekly progress report on the specific project. Possible modifications from the original plan will be discussed and analyzed. On the other hand, the final project will be presented in video format (which should last no more than 10 minutes) and will be posted in Youtube (http://www.youtube.com/watch?v=NuIM_Ne5pvM) [23].

In addition, students will have to hand in written reports both from the initial project and the final one. These written exercises together with the video will be peer-assessed and defended in front of a jury formed by 3 professors from the Projects Department.

2.- Activity in English

2.1.- This 2h activity consists in explaining how to plan and conduct an oral presentation in English (theory) and practicing it later on. The professor spends between 30 minutes to an hour explaining how to present orally in this foreign language: organization of contents, use of sequencers and discourse markers, description of figures in pie charts, bar graphs, etc.) Not to mention, students are given all the vocabulary required to perform their presentation in English and, moreover, they also work on a divulging research paper from their studies specialization. After, students prepare their own presentation on the article during 30 minutes in the computer lab. Finally, their presentation is assessed by both their classmates and the two professors involved in the acti vity (an English teache r and a professor from their specialty).

2.2.-Development of Portfolios or Wikis in English from one to a group of subjects [24,25].

3.- Creating Jigsaws and/ or crosswords using the specific vocabulary used in each particular subject and online questionnaires (Using Moodle for example). They could be learning exercises or follow -up activities before an exam to revise core content. These and other activities carried out in our study can benefit from the use of a platform where students can participate in a discussion forum and/or an exchange materials and store different contents. In the UPC we mainly used the Basic Support for Collaborative Work BSCW [2, 17,18] from the Engineering projects Department server.

IV. RESULTS

A. *Comparing percentage marks of first year subjects.*

In this initial part of the study we compared three subjects of the first academic year in the three different degrees.

Therefore, in this section we present the percentage of marks obtained in the three subjects when AL methodologies were introduced and compare the results with the marks from previous academic years when such methodologies had not been implemented in the classroom. As we have mentioned before, we only considered those subjects taught by the same professor in different academ ic years and using different teaching/learning methodologies.

In Table 1 it is shown the percentage of marks obtained by students from academic years 2004 /2005 and 2005/2006, in which CL activities were introduced in a subject from the Environmental Sciences degree and comparing such percentages with the ones resulting from previous academic years when a more traditional methodology (based on the lecturing method) was used.

TABLE I. PERCENTAGE OF THE MARKS OBTAINED IN THE SUBJECT THROUGHOUT SEVERAL ACADEMIC YEARS.

n=nº students	Percentage of marks according to the total number of students (%)				
	AB	F	P	VG	EX
A. Year 01/02 (n=45)	4	40	41	13	2
A. Year 02/03 (n=29)	3	37	40	13	7
A. Year 03/04 (n=17)	19	33	33	15	0
A. Year 04/05 (n=16)	31	30	19	13	7
A. Year 05/06 (n=20)	10	21	25	23	21

This traditional methodology was based on professors' lectures and was complemented with practical exercises to reinforce the contents given in class. In those academic years the percentage of passing marks were of 56%, 60%, 48% respectively and it is during the academic year 2004/2005 when CL methodology is firstly introduced in this subject and activities are designed to cover approximately 30% of its syllabus. To this respect, we can observe that the total percentage of passing marks is 39%, which compared to the results from previous academic years is a considerable drop. We could explain this figure by taking into account that there seems to be an increase in Non Presented students AB (31%) as the percentage of passing marks compared to the total number of presented students is 67%. (From now on we will use the following abbreviations: AB as "Absent ", F as "Fail", P for "Pass", VG "Very good" and EX for "Excellent").

On the other hand, during the academic year 05/06 the amount of l ectures is reduced to 20 % of the syllabus and the rest of the core contents are worked through CL activities. We can see that this year the p ercentage of students increases significantly (69%) and the number of a bsenteeism is reduced when comparing with the percentages of the two previous academic years. At the same time, there also exists a significant increase in the percentage of VG and EX making the same comparison. Therefore, we could say that the more implementation there is of AL methodologies, the more familiar students become with them and this fact could explain the better results they obtain in academic years 04/05.

1) A. Comments:

The several changes made throughout the two academic years when AL methodologies were implemented together with the increasing experience of the professors involved in such challenge could imply that students may improve their results when most of the s yllabus is taught through an AL approach. We could also relate this success to the increasing number of subjects including AL methodologies during the second academic year within the Institution and, hence, to the greater familiarity of students with these new teaching and learning tools.

As a matter of facts students need to know about each institution's culture towards the use of new methodologies in the learning process. As we can see in the available literature on this topic such requirement also appear s in other pilot studies, as in [9][12][13][17] , which are examples mainly taking place at university level.

Another aspect to highlight from the results obtained in our study is the increase of VG and EX marks if compared with students' grades from prev ious academic years. It seems, then, that these active methodologies enhance and guarantee a greater learning of the students who join and involve themselves in the dynamics of the subject. Moreover, this sample of students (n) find AL activities more motivating than the traditional ones and this fact, in return, is reflected in their academic results. [17].

1st year subject in Telecom Engineering, specific branch of Sound and Vision. This is a practical subject which underwent the European Credit Transfer System (ECTS) adaptation during the academic year 05/06, which decreased the number of lecturing sessions to 20% and organized the rest of the tuition using CL activities.

According to our results it seems that the introduction of this methodology increases the percentage of AB and F students if compared to an academic year where traditional methodology was in use (15%). At first, we could think that some students may be reluctant to get involved into such new methodological approaches and so drop out the courses. However, as previously seen in the Environmental Sciences subject, results show an obvious increase in the total number of students obtaining the highest marks possible (VG and EX) in the academic year 2005/06 moving from 42% to 63%.

In previous studies [22], it has been shown that the implementation of these methodologies in practical subjects' results in raising the number of VG and EX but, at the same time, the amount of AB and F, therefore validating the results obtained in the present study.

At this point, we should reflect and consider the existence of other possible factors which could affect students' behavior. This would be the case of the degree of maturity of each individual, the familiarity of the student with AL approaches in other subjects or contrary to it, the lack of knowledge and/or practice of such learning tools or the low interest of students in them.

In the 1st year subject of the Industrial Engineering degree during the academic year 05/06 the number of tuition using the lecturing method is reduced to 40% and the remaining 60% is carried out by developing CL activities. And again, our results clearly repeat the trend identified in the preceding sections.

This fact shows that although some students do not get involved when using this active methodology, the ones who do increase their interest and motivation toward the subject in particular and they finally learn more and obtain higher marks.

B. Survey results on the satisfaction of students towards the implemented methodology.

The assessment on the introduction of the methodology has been carried out taking into account the students' view, obtained by filling an anonymous questionnaire on their satisfaction with the CL methodology at the end of the course. A complete sample of the survey is included in the following paper [22].

In this study, we have calculated the percentage of students who "agree" or "very much agree" with each question in the survey. A unique percentage is shown when no significant differences are found between the three subjects studied, in which case the percentage equals the total sample analysed.

One of the most relevant points is the section which deals with questions related to the learning process. In this part we can point out the following results:

91% of the students claim that they have learnt and understood the contents of the course.

63% of the Telecom and Industrial Engineering students think that the introduction of this new methodology has increased their interest in the subject while only 30% of the Environmental Sciences students agree with the methodology used.

As to competencies enhancement, 48% of the students agree with the claim that these activities have improved their oral skills and 40% consider them a key factor in the development of their written abilities. However, it is significant that although all the activities had been designed and planned to reinforce both competencies more than 50% of the students disagree. These results could be argued if we consider that a semester is insufficient time for students to perceive any progress in the development of their oral and written skills and, hence, they should keep working on such competencies in the following academic years.

70% of the students claim that this methodology helps developing their capacity to synthesize and understand information which, in fact, is one of the main targeted competencies in the EHEA.

85% of the Telecom and Industrial Engineering students think that this AL methodology has enhanced both team work and debate of information, as it is also observed in a similar study in this field [15].

In addition, 68% of the students in the sample consider this methodology as a key factor in increasing their ability in planning and time management. In fact, the activities were designed taking into account that such competencies are crucial for first year students and, therefore, should be emphasized and our results show that the implementation of AL methodologies in the hard sciences succeeded in this sense.

The following matter to be tackled was planning, and in here we would like to point out that 75% of the students in our survey found that their professor's objectives totally coincided with what was taught in the classroom.

However, we could observe varied opinions when students from different academic backgrounds assessed the preparation of the materials delivered by the professor in each subject. (See Telecom and Industrial Engineering 74% and Environmental Sciences 57% respectively).

Another relevant piece of information is drawn by the figures we obtained concerning team work sessions as 100% of Telecom Engineering students, 78% of Industrial Engineering and 43% of Environmental Sciences claim that those sessions were very useful and well-organized.

Besides from the data collected in the students' questionnaires, most of them think that the activities designed targeting AL methodologies implementation meant a greater workload and a consequent lack of time to carry them out. Thereby, professors should think about restructuring activities timing for the following academic years.

In the case of the subject taught in the Environmental Sciences degree, the professor has been incorporating this type of methodology steadily and confirms that teachers need a learning period to design the activities carefully and implement them properly in the class. This opinion is common to all the authors who consider that these kind of methodologies should be implemented in the subjects gradually with an improving period for the activities chosen of approximately 3 academic years [12, 26,27].

As to the results concerning assessment, 65% of the students in the 3 different degrees claim that team work evaluation has been fair and has helped improving the learning process throughout the whole year.

C. *Students' performance according to degree and cycle*

Once the study presented here was finished and we had carefully considered its results, another question came into our minds: whether these AL methodologies were equally considered across the different academic cycle or significant differences would appear. Through such results we would be able to verify and, after, validate behavior patterns within the same degree and also check for any repetition pattern occurring in each degree or cycle.

With this goal in mind we selected subjects from the first and second cycles in several degrees. The resulting figures were compared to subjects (within the same cycle) which did not incorporate any AL methodology in the classroom.

After introducing these new methodologies in the degree of Environmental Sciences we could observe a significant decrease of P (28 %) corroborating, then, the results initially obtained when only considering first year subjects and finding exactly the same patterns in the degree.

On the other hand, in the first cycle of the Telecom Engineering degree there seems to be a clear increase in the percentage of passing marks (P) when using AL methodologies. At this point, we would like to emphasize that the higher number of students' marks belong to the categories of (P) and (VG) and there is a decrease of students obtaining (F).

Finally, in Industrial Engineering first cycle we have also detected an increase in the percentages of (P) and (VG) with the implementation of such methodologies but the improvement in student's marks is even greater during the second cycle.

Hence, we could conclude that in Telecom and Industrial Engineering the introduction of LA methodologies generally improves the performance of students in the two different cycles.

D. *Professors' Global Evaluation*

So as to know the degree of influence of the introduction of AL methodologies in students' assessment of their professors' performance, we have analysed the results of university questionnaires on students' satisfaction taking into account and, thus, comparing the subjects following a Cooperative Learning (CL) approach and the ones with a more traditional learning approach in those surveys where students showed a lesser agreement with CL, that is to say, Environmental Sciences and Industrial Engineering.

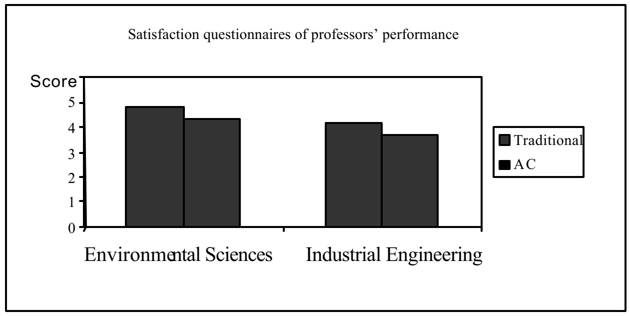

Figure 1. Student's results on satisfaction questionnaires of professors' performance.

According to the results shown in Figure 1 there are no significant differences in the global assessment given to professors regardless of the learning methodology used and the satisfaction of the students with it.

Focusing on each degree analysed, we could see that there is a slight change in Telecom Engineering results and there is a significant increase in the case of Industrial Engineering.

Among the several experiences carried out in the Polytechnic University of Catalonia (UPC), it is precisely in the Technical School of Castelldefels where a pilot plan for new learning methodologies in the classroom was implemented and where, in addition, specialized professors provided staff from the same university or others in Spain with the suitable teachers' training (later on). [28].

We could say that there is a set of key factors that could improve professor's assessment by students, among others, student's familiarity with the new methodologies used in the classroom and the proficiency and skill of professors in their application.

So as to assess the latter factor (professors self-assurance) a set of questions was developed after a School's Symposium in the EPSEVG Centre (UPC) [29][30]. Our aim was to find out which methodologies were familiar to the professors attending the event and which ones were applied or were to be implemented soon. Not to mention, grading their precise level of self-confidence during the process.

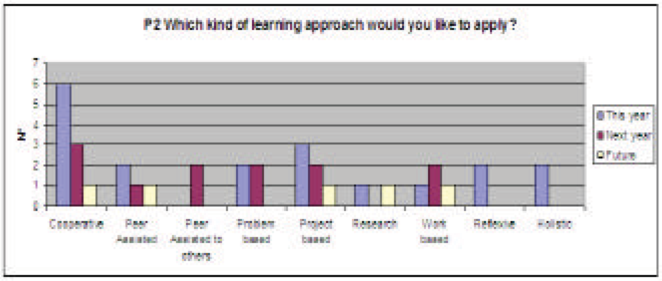

Figure 2. Professors' answers on their knowledge of methodologies, their application and future plans of implementation.

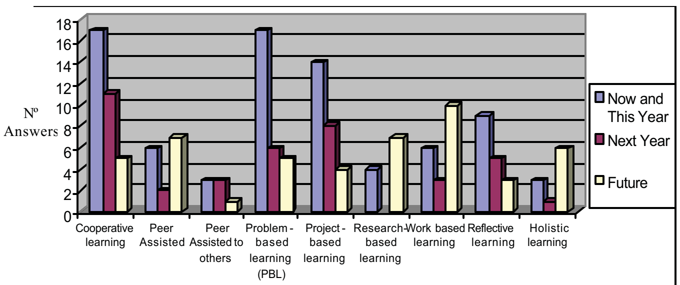

Figure 3. Professors' answers on their knowledge of methodologies, their application and future plans of implementation.

In 2008, we passed again the same test to several teachers from different Engineering Schools in Spain and France. Figures 2 and 3 show that the CL method was the most used during recent academic years but in Figure 3 we can see that two new methods have been used in the same proportion as CL: Problem Based learning and Project Based learning (this fact was shown by other studies). Moreover, we can also observe that some professors plan to use the Work Based Learning (WBL) methodology in the near future. In conclusion, our study can confirm that university teachers use new learning methods increasingly in order to be totally integrated in the EHEA in 2010.

V. CONCLUSION

The results presented in this paper show that the implementation of CL and PBL methodologies in first year subjects of three hard sciences degrees is positive. In addition, when comparing our results with the ones obtained by GREIDI (GRupo de Estudio en Innovación Docente en Ingeniería Universidad de Valladolid) group in academic years 2005 -2006 [2], we can see that the trends totally coincide, hence, validating our findings. In this sense, university students learn core concepts from each subject as well as enhance their oral skills, teamwork ability, planning competence and even leadership. Not to mention, their capacity of synthesizing and understanding the information given in each activity (especially designed by the professor for each subject in particular). We could say that all these elements will contribute to make students ready for the following subjects in their curriculum and to develop the competencies required in their professional career. [31, 2].

On the other hand, ICTs play a key role in the "newly" designed activities and constitute a solid platform or support for the subject's planning, material sharing and management by both students and professors. Therefore, our first conclusion would suggest that CL and PBL implementation is positive and suitable for the different technical subjects selected in this study, regardless of their contents.

Furthermore, this work shows that students are required a greater effort when using these AL methodologies but the more involved in them, the better results students obtain.

In the latter study concerning the comparison of results in terms of acceptance of AL methodologies implementation in different cycles and degrees, we can generally confirm students' higher performance but, at the same time, possibly because of their lack of awareness of their expected higher degree of involvement in such type of methodologies, there may exist some confusion among students and, hence, the is no acceptance patterns when considering academic cycles. Finally, we have observed professors greater self-assurance and experience in new methodologies implementation, which will, in turn, help students acquire more knowledge, training and confidence in its application in the classroom.

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Attracting, Retaining, and Preparing *a* Diverse Academic Engineering Workforce:

The AGEP Model for Success

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Abstract— The National Science Foundation (NSF) has recognized that the Nation's need for a technical workforce is in conflict with the changing demographics facing the nation. Our nation is rapidly becoming more diverse due to growth in groups that have traditionally been underrepresented in technical fields. Nowhere is this underrepresentation more evident than in academia. It was determined that one potential way to attract more underrepresented students to pursue engineering careers was to increase the diversity of the engineering faculty, proving powerful role models to potential technical students. Therefore, over 10 years ago, NSF began a program that sought to

diversify the Nation's faculty in engineering, science and mathematics fields, called the Alliances for Graduate Education and the Professoriate (AGEP). The AGEP Program is now a national network of multi-institution alliances. Nationally, the AGEP program has recorded significant gains in doctoral degrees awarded to underrepresented minorities in engineering. The Southeast Alliance for Graduate Education and the Professoriate (SEAGEP) Program includes the University of Florida, Clemson University, and the University of South Carolina. SEAGEP is the top producer of Hispanic PhDs in the country and is third in the production of African American PhDs in engineering. Best practices in recruiting, retention, and preparation for the professoriate are detailed.

Keywords̃ retention, professional development, engineering faculty, diversity

I. Introduction The United States is facing changing demographics that have potentially important implications for engineering education in the future. Today, the U.S. workforce includes 20.8% African Americans and Hispanics, according to W. Lance Haworth of the NSF Office of Integrative Activities [1]. Projections are that these two groups will grow to comprise 29.8% of the total workforce of 2020 [2]. Additionally, it is estimated that by 2050, a full

50% of the U.S. college-age population will be from underrepresented minority groups [2].

However, despite the increase in the workforce pool, these groups have not traditionally pursued engineering and science academic careers. In 2003, less than 17% of those earning science, technology, engineering and mathematics doctoral degrees planned to pursue an academic career [3]. Underrepresented minorities accounted for only 7.9% of all science and engineering doctorate-held academic positions in universities and four-year colleges in 2003 [3].

As Figure 1 shows, the number of underrepresented minorities receiving doctoral degrees in science and engineering has risen in the period from 1990 to 2006, but remains low, at only 10% of all doctoral degrees awarded in science and engineering to U.S. citizens [4].

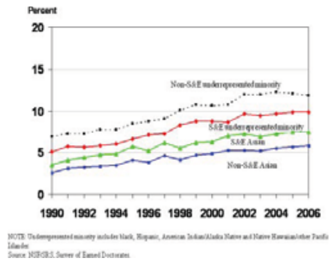

Fig. 1. Minority share of science and engineering and non-science and engineering doctoral degrees to U.S. citizens: 1990–2006.

Figure 2 illustrates the dramatic disparity between employment of majority and underrepresented minority faculty [4].

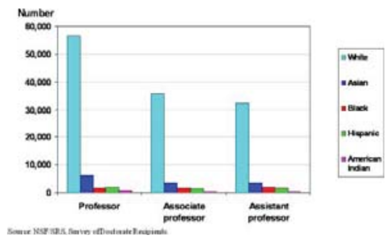

Fig. 2. U.S. citizen science and engineering doctorate faculty employed in universities and four-year colleges, by race/ethnicity and rank: 2006.

If no changes are made in science and engineering education that result in more representation from these groups, predictions are that the disparity will widen [5].

To address this issue, the National Science Foundation established a program in 1998 designed to diversify the student population pursuing doctoral degrees in science, engineering and mathematics. The Alliances for Graduate Education and the Professoriate (AGEP) program was designed to increase the number of domestic students receiving doctoral degrees in science, engineering and mathematics with special emphasis on those population groups underrepresented in these fields to prepare them for careers as faculty and research professionals.

The goals of all AGEPs include developing infrastructure that substantially changes the graduate school experience for underrepresented minority students and catalyzing institutional change. One of the major obstacles faced by underrepresented minorities that must be addressed if an institution wants to attract and retain a diverse student population is the lack of culturally appropriate student support systems. AGEP institutions address this obstacle directly. This national network of programs now includes 21 alliances that represent over 80 institutions [6].

NSF collaborates with the American Association for the Advancement of Science (AAAS) to evaluate the effectiveness of the AGEP program. A recent AAAS report provided an analysis of doctoral degree recipients from participating AGEP universities and revealed that in the first ten years of the program, the annual number of doctoral degrees awarded to underrepresented minorities in science and technical fields increased by 33.9%. The natural sciences and engineering fields reported an increase of 50%. In 2005-2006, the AGEP alliances produced 56% of all science, technology, engineering and mathematics doctoral degrees awarded to underrepresented minorities in the United States [5].

The University of Florida was awarded an AGEP in 1998, and five years later the project grew to include Clemson University and the University of South Carolina in the South East AGEP (SEAGEP). This group has implemented a variety of measures to develop a robust recruiting, retention and doctoral degree completion program impacting graduate programs in science, technology, engineering and mathematics. Additionally, professional preparation for academic careers is part of the program. The University of Florida has developed a mature program and is now the fourth-highest producer of Hispanic PhD graduates in engineering and the third highest producer of African American PhD graduates in engineering [7]. Both Clemson University and the University of South Carolina have been working to implement a similar infrastructure to enhance the diversity of their graduate programs in science, technology, engineering, and mathematics. The key elements in the SEAGEP program are described below.

II. Key Elements

The most essential component of a diversity program is support from top university administrators. Diversity at all levels should be a visible part of an institution's mission. However, beyond mere recognition of the need for inclusivity in institutional mission statements, some type of accountability structure should be in place. For example, at one of the SEAGEP institutions, the Graduate Dean has implemented a policy whereby graduate program reviews will include a diversity dimension; i.e., a department's record of awarding degrees to underrepresented minority students will, in part, determine allocation of resources from the Graduate School.

At Clemson University, oversight of the diversity mission of an institution rests with a Chief Diversity Officer. The Chief Diversity Officer reports directly to the President and provides leadership in implementing Clemson University's first Diversity Plan. The Chief Diversity Officer leads all efforts designed to foster a learning and workplace environment that is welcoming and supportive for all students, faculty, and staff. The Chief Diversity Officer supports existing diversity activities and develops and implements new initiatives and programs to provide focus and accountability for equity and inclusion across the university. Among the tasks of the Chief Diversity Officer is sponsoring of the annual National Conference on Best Practices in Black Student Achievement at Clemson University. Each year administrators, staff, and faculty who help universities recruit, retain and graduate African-American students at academic institutions across the country attend this conference, which provides a venue for dissemination of SEAGEP best practices.

At the University of Florida, Dr. Bernard Machen established the President’s Council on Diversity, which has been charged with the mission of gathering and analyzing diversity data at the college and departmental levels. The Council on Diversity has been formed to further the University’s commitment to equal opportunity. The President’s Council on Diversity is also charged with identifying ways to increase the diversity of the faculty, staff and students. The council is currently working to review the practices of each college and department within the University of Florida to determine whether improvements could be made to increase student, staff, and/or faculty diversity and to propose policies that serve to increase/retain underrepresented minority students, staff, and/or faculty.

The University of South Carolina has instituted a new set of Family Friendly policies, which is an initiative of the Office of the Provost. All science and engineering units have been encouraged to increase the number of female and underrepresented minority faculty. The new Assistant Dean for Women and Minorities in the University of South Carolina College of Engineering and Computing is tasked with assisting departments with identifying and recruiting underrepresented minority faculty.

The second component of a successful diversity program is comprehensive data collection capability. Defining an institution’s historical baseline as well as tracking current students requires a robust dataset that is not necessarily collected systematically by departments and graduate schools or readily obtainable from offices of institutional research.

AGEP institutions collect and report the following numbers annually: applications, admissions, new enrollees, total enrollees, admit to candidacy, and degrees awarded. These are disaggregated by field (engineering, chemistry, physics, mathematics, computer science, biological and agricultural, earth, atmospheric, and ocean science), race, ethnicity, and gender for a total picture of the graduate student population.

Pre-AGEP, this annual institutional snapshot was not collected at the University of Florida, Clemson University, or the University of South Carolina. The data not only can be used to identify trends, but also may indicate fields that are performing below national standards. Furthermore, the data may also indicate where interventions are needed. For example, if the data show that numbers of applications and admissions are increasing, but that this increase is not reflected by numbers of new enrollees, it would be appropriate to identify ways to increase the yield of admitted students.

Additionally, these data can serve whatever accountability systems are put in place, because they reveal departments that are performing below institutional standards. The data are shared with Deans to allow them to monitor their programs. This data collection and analysis effort also provides critical information for PIs seeking funding for diversity-related proposals.

Third, a highly visible office on campus should be established that includes space for students to meet. This legitimizes the program on campus and provides a physical presence that demonstrates the instruction’s commitment to students’ success. It also supports regularly scheduled professional development seminars and other student activities. A program budget to support program activities is critical. This should include funds to maintain the office as well as providing funds to support student travel and other student activities.

A Program Director who reports to upper administration is the final infrastructure requirement. This person has significant student advising responsibilities in addition to project management duties.

II. Program Activities: Recruiting

Recruiting for diversity is a critical first step, but one not always conducted or understood at the graduate student level. Unlike centralized undergraduate admission, graduate admission is a decentralized, often faculty-driven activity. At large institutions, some faculty do not actively recruit, but rely on students who contact them or who are already admitted into the department. These methods tend to exclude those outside of traditional engineering groups.

An active diversity recruiting program is needed, but to be successful it must be based on personal connections with those institutions and programs that support underrepresented minority undergraduates in the science, technology, engineering and mathematics disciplines. Including current underrepresented minority graduate students as recruiters is a powerful tool. SEAGEP has established a recruiting network that includes the National Science Foundation keystone program for underrepresented minorities, the Louis B. Stokes Alliances for Minority Participation in Science, Technology, Engineering, and Mathematics (AMP). SEAGEP participates in recruiting events at both the Florida-Georgia and South Carolina AMP programs, as well as at the University of the Virgin Islands.

In addition, a unique recruiting tool has been the establishment of a dual-degree program in engineering between the University of the Virgin Islands, the University of Florida, and soon the two South Carolina institutions. These programs allow the students from the University of the Virgin Islands to obtain an engineering degree that would otherwise not be available to them on their home campuses.

A major component of preparing undergraduate students for graduate school is undergraduate research. SEAGEP institutions therefore have supported a variety of undergraduate research efforts. These include academic year research at a student's home institution as well as summer residential research experiences. These experiences provide undergraduates with laboratory skills and graduate student mentors to increase their awareness of the graduate school experience. In addition, SEAGEP has sponsored several international undergraduate research experiences in Finland and Costa Rica.

III. Retention

Too often, it is assumed that once underrepresented minority students have been accepted, the process of diversifying the student population is over. Without a strong retention program, however, many of these recruits will be lost before they earn the doctoral degree. This component requires both human and financial resources. Underrepresented minority students often face unique challenges in science, technology, engineering and mathematics fields, including isolation and lack of awareness of the doctoral degree process, which require mentoring by program administrators. Having support outside of the department can be instrumental to a student's success. In addition, many of these students face greater financial obstacles than do majority students, and consequently seek outside employment that detracts from their academic responsibilities.

It proved critical to the retention of a significant number of SEAGEP students to provide short-term stopgap funding to bridge other funding opportunities. These retention awards were a key factor in maintaining an overall retention rate of over 80% to the Ph.D, a rate significantly better than the retention rate for non-SEAGEP students.

IV. Professional Development

In order to prepare students for academic careers, the AGEP program provides a portfolio of professional development activities. This includes both in-house and national preparation for the professoriate seminars and workshops. SEAGEP not only funds development, coordination, archiving, and online delivery of the professional development programs at the alliance institutions, but it also provides considerable travel funding to send students to professional society meetings. Participation in professional meetings is especially important for underrepresented minority graduate students as it gives them critical networking opportunities and provides entrée to an extended discipline-specific community.

SEAGEP funds are allocated to support development, archiving, and online delivery of the Clemson University Engineering and Science Education certificate and the associated seminar series. The graduate certificate program, one of only a handful in the United States, is designed for graduate students who seek experience in preparation for an academic career, who wish to further their understanding of the education process in engineering and science, or who are interested in engineering and science education research. The Engineering Science and Education seminar series is a one-credit course designed to bring contemporary issues in engineering and science education research into the classroom. Experts from academia, industry, and the corporate world are invited to make presentations on engineering and science education research issues including recruitment of minorities, retention issues, technology integration into engineering curricula, distance learning, engineering content into K-12 curriculum, learning theories, and education policy issues.

Global research experience is also a critical component for students' professional development. SEAGEP has been able to help support students with international research awards to conduct research in Bolivia, Columbia, Costa Rica, and Honduras.

To provide students with critical leadership skills, a SEAGEP Student Leadership Council has been developed. This group assumes the responsibility for planning student events such as the fall new student orientation and the annual student meeting, which features several days of professional development workshops and a scientific poster session.

V. Post Doctoral Project

To support the AGEP mission of diversifying the professoriate, SEAGEP provides funding for postdoctoral positions. Faculty partnered with SEAGEP to recruit underrepresented minority postdoctoral researchers in Zoology, Materials Science and Engineering, Chemistry Botany. Astronomy, and Microbiology and Cell Science at the University of Florida.

Feedback regarding this aspect of the program includes:

> *This post doc has been critical for his development. His writing and presentation skills have improved immensely and instead of giving up on a career in academics, he is now poised to land a nice professorship at a small college in the south.*

> *Having a longer postdoctoral study period really allowed her to develop her own unique research program. She was hired as a faculty member at Colgate College last Fall, and from what she has told me, she has hit the ground running with an active research program.*

Both the University of South Carolina and Clemson University participate in a Minority Postdoctoral Academic Career Training Program that is managed and funded by the State EPSCoR/IDEA program. In 2007, two of the five postdoctoral students supported were from the University of South Carolina, and one was from Clemson University. These students were provided a full year of support, and spent part of the year teaching at either a minority-serving institution or a primarily undergraduate institution.

VI. SEAGEP Alumni

To date, University of Florida SEAGEP has graduated 38 PhD students representing 28 departments in engineering and science. Of these, 8 are in academic positions, 14 are currently in postdoctoral positions, 8 are in government, and 8 are in industry. Of those not currently in academic positions, several have indicated an interest in joining academia at a later date. Interviews with this group indicated their belief that without the SEAGEP program they would not have successfully completed their degrees.

VII. Evaluation

The national data collection effort described earlier has shown an increase of 40% in PhD enrollments in the Biological & Agricultural Sciences in SEAGEP in the past 5 years and a 13% increase in PhD enrollments in Engineering. This was accompanied by a 27% increase in PhD degrees awarded in the Biological & Agricultural Sciences and a 20% in Engineering. In addition to this national data, the SEAGEP program has been extensively evaluated on several levels to determine what program components are most beneficial to the students, what the overall student experience is, and how this experience differs from other graduate students' experiences. Both quantitative and qualitative data has been collected. Mixed methods including focus groups, surveys, and interviews have been used. This methodological triangulation approach has produced a rich body of data that points to the success of the program at supporting and graduating increased numbers of underrepresented PhDs in science, engineering, and mathematics.

As mentioned earlier a significant obstacle to student success is the lack of appropriate support structures. SEAGEP students who were interviewed noted that the greatest benefit of the program came from the support they received as members of the SEAGEP community. Such support came through (a) monthly SEAGEP meetings, (b) dedicated SEAGEP administrators and staff, and (c) peer support, both academic and social.

The monthly meetings provide a forum for students to get to know each other, develop friendships, get advice from their peers, develop peer mentoring relationships. The meetings also provided them with a group of students that they encountered on campus at other functions. As one student explained:

So the only real support system I have from people from similar backgrounds is basically AGEP and some friends that I have, but mostly just AGEP. It's not that it's a problem having friends of different racial backgrounds, but I think you need to have that blend. Without this particular program I wouldn't have had that blend. It is not always easy or convenient to stop what you're doing and come over [to the monthly meetings], but it is definitely beneficial for me.

As for the importance of dedicated personnel, students commented that they are

people you can call on to say you are having a problem and get advice. And that is probably the most invaluable part of the program. A lot of programs offer money but they don't try to help to see your way through the program. You are pretty much left on your own. Here they try to cover all your bases.

With respect to the importance of helping students overcome isolation, comments included:

Since I am the only AGEP student in my department, I get to see other students in other majors and see what they are doing, see how their programs work and have the advantage of being able to know how other departments do their thing.

Some of the other programs, organizations, their meetings don't have that continuity, you don't have the family environment – you don't get that feeling, you don't know everyone in the same program. You can talk to someone on a given day and they will say, "Oh, I'm a member of that too."

As important participants, Deans, Department Chairs, and faculty advisors were also surveyed to determine the effect of the program on them. Sample comments included:

The program has greatly enhanced our ability to recruit and to nurture minority women for engineering education; in my case for the rapidly growing biomedical materials field where they will have the opportunity to become leaders in this field in R&D or education and become role models for a new and more diverse generation of women in biomedical engineering . . . The program has allowed us to focus on recruitment to strengthen diversity.

We also have added the outcome of placement of our PhD graduates into the professoriate as an important measure of success. Many of our departmental graduate staff members are using this opportunity to recruit students from these groups.

Indirectly, the Program has helped intensify our recruitment of students from traditionally underrepresented groups in ---. The Department now supports faculty visits to the national meetings organized by [National Societies for Underrepresented Groups].

To gain a richer picture of the graduate student experience in SEAGEP, a recent study was completed that included a survey of both SEAGEP students and a matching group of majority students to allow for comparison of the graduate school experience of the two groups. These results will be reported elsewhere, but preliminary analysis indicates that the difference between the graduate experience of SEAGEP students and the graduate experience on non-SEAGEP students is not statistically significant with regard to a wide range of issues concerning satisfaction with their program and quality of life issues. Those areas that do show a difference will be used to improve mentoring, advising and other areas as appropriate.

VIII. Summary

As the National Science Board notes,

Governments throughout the world recognize that a high-skill science and engineering workforce is essential for economic strength. Countries beyond the United States have been taking action to increase the capacity of their higher education systems, attract foreign students and workers, and raise the attractiveness to their own citizenry of staying of staying home or returning from abroad to serve growing national economies and research enterprises. [8]

While it is critical to the United States that the diversity of its research enterprise reflects the diversity of thought and opinion of all of its peoples, this is equally important across the globe. Reports from Australia, Canada, and Kenya indicate demographic changes in the student populations pursuing advanced degrees, and an awareness that these changes require a closer look at issues related to diversity.

Researchers in Canada have noted that increases in the non-White population are significant and that this makes it increasingly important to understand the factors of attrition and retention as they are related to racial origins and campus climate [9,10]. Researchers in Kenya have also studied ethnic diversity as it is affected by policy decisions in higher education [11]. In Australia, the growth from 8,563 doctoral students in 1988 to 39,531 in 2004 resulted in significant increases in the heterogeneity of students [12] and prompted studies of the impacts of policy on diversity. Diversity enriches the research and teaching enterprise, and it is clear that the increase in diversity of students pursuing advanced degrees is a global phenomenon. It is also clear that research into the issues faced by specific groups of students can result in programming and policy decisions that will enhance rather than hinder the success of these students who were previously not part of this enterprise. While diversification of the student population is a global experience, as conditions and obstacles vary from country to country, it will be up to education researchers in each to determine what the specific challenges faced by minority students are, and to make recommendations to ameliorate them. With respect to programming specifically designed to ensure retention and graduation of underrepresented students in science, engineering, and mathematics in the U.S., the AGEP program has demonstrated that achieving an increase in the diversity of students pursuing advanced science and engineering degrees requires dedicated personnel and a comprehensive approach that supports the students throughout the entire process. The model developed by the institutions in the Alliances for Graduate Education and the Professoriate is being used effectively in the production of doctoral degrees in engineering and science fields.

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Session 11C Area 2: Design Experiences - Tools and procedures

Design lab work in telecom

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Deep Drawing Tool for E-learning

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A review of electronic engineering design free software tools

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Design of an Educational Oscilloscope

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Design lab work in telecom

Definition, design and test of a wireless sensor network

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***Abstract*— This paper describes a teaching experience where Master 2 students have to solve a telecommunication problem without having specific theoretical required knowledge but using an experimental hands-on approach.**

Keywords-Telecom networks, Architecture and Protocol, Tests

I. INTRODUCTION

A. Problematic

Various issues can be considered during a lecture on wireless sensor networks [1], [2]: electronic design, risk for the human being, management of the energy, technologies of telecommunication, signaling and communication protocols… The education experiment described in this paper essentially aims at making future graduates to acquire the basic knowledge needed to choose between several software and hardware telecommunication architectures more or less adapted to a context, and to help them to evaluate the consequences of their choices on the software development associated to the each device. In that context, various telecommunication technologies used in personal networks (*PAN* for *Personal Area Network*) are nowadays potentially answering such needs such as remote monitoring of buildings, care of the elderly, structural health monitoring [3]…

B. Paper structure

The paper is structured in the following way. Section 2 presents the context and the objectives of a teaching experiment dealing with the implementation of a platform dedicated to test of several wireless sensor networks. Section 3 details the various technologies considered for telecommunication devices. Section 4 describes the methodology used by the teachers so that the students manage by themselves to find an answer to the question: "for a given configuration, what device is the most appropriate and what is the associated software development?" The concluding section gives the first conclusions on this teaching experiment as obtained from the student feedback.

II. IMPLEMENTATION

A. Context and objectives

In the AE (Automatic Control and Electronics) curriculum of the INSA Toulouse [4], considering issues related to the sensor networks, the students attend lectures about analog and digital electronics, communication networks (e.g. Internet) and telecommunication principles. There is no specific lecture on sensor networks. The objective of the experiment described in this paper is to get students acquiring software and hardware skills in heterogeneous wireless sensor networks. The goal is reached following an auto-training pedagogy such as the ones detailed in *Problem-Based Learning* [5], [6]. The students have to develop an experimental platform to test different telecommunication devices usually employed for personal area networks on one hand and to test different protocols involved in communication between wireless sensors and remote customers on the other hand.

B. Application description

The students have to develop an application of remote monitoring of several parameters of a room (luminosity, temperature) and of movements (intrusion in the room or displacement of one object inside the room). This application is based on terminal nodes made up of a sensor, a microcontroller and a telecommunication module. Several buildings can be inter-connected while the sensors inside each building must keep interacting, as illustrated in Fig. 1. Three families of nodes are used. These families have been chosen according to the data they have to transmit. Those data are different by their:

- Nature: some are binary (e.g. detection of a threshold), others are analogical ones;
- Criticality: processing data can be more or less critical;
- Periodicity: some data must be sent periodically, while other transmissions are event-triggered…

As far as their transfer is concerned, these data have different needs concerning the quality of service. These needs must be taken into account for the choice of a specific telecommunication technology and during the development of appropriate communication protocols.

The network is constituted of terminal nodes, gateways embedding various telecommunication devices and of a main station able to maintain communication with a remote user.

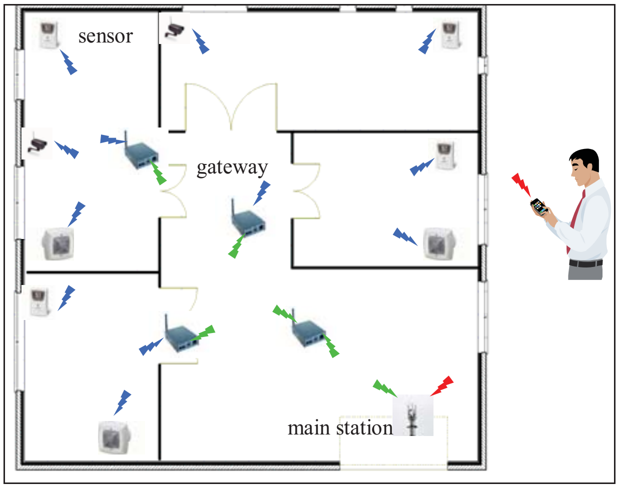

Figure 1. Example of a wireless sensor network

III. A SELECTION OF TECHNOLOGIES TO BE INVESTIGATED

This section presents the various telecommunication devices involved in the network as well as the various protocols which the students have to set up. Devices are connected via customized boards to the evaluation board of a microcontroller (MCBSTM32 [7] of *Keil*, processor ARM / ST). This configuration represents a "less embedded" solution than a dedicated electronic board which would have specifically been developed but it offers a high flexibility of use and of debug to the students by supplying a multi line LCD screen for display, free zones for oscilloscope test points, series connections to a terminal PC, diodes... The communication and signaling protocols are implemented on the microcontroller by means of the environment *μVision3* of *Keil* [8] which offers functions of simulation and transfer towards a microcontroller.

A. *Telecom devices*

Three technologies of devices are selected for this teaching lab work:

- A half-duplex transmitter using FSK modulation at 433MHz manufactured by Telital;
- An IEEE 802.15.4 transmitter manufactured by Microchip;
- A GSM / GPRS modem manufactured by Sagem.

The choice of these technologies is driven by the diversity of the services that they offer and by the diversity of their service access. The presentation of these services is the object of section B. The presentation of the service access is given below. Table 1 roughly summarizes the characteristics of these modules, the objective of the student lab work being to refine and to extend this table. The symbol "O" means an average performance, the symbol "+" a performance superior to average, and the symbol "-" a performance below average.

TABLE I. MAIN DEVICE CHARACTERISTICS

Device	Characteristics			
	Cost[a]	***Range***	***Access***	***Energy***
802.15.4	O	O	SPI	O
FM 433MHz	+	-	RS232	+
GSM/GPRS	-	+	RS232/AT	-

a. Initial and use cost

The column "Access" indicates the bus which must be used between the telecommunication device and the microcontroller to reach the communication services. Two buses are available: the RS232 bus which is implemented by a connection USART (*Universal Synchronous and Asynchronous Receiver Transmitter*) of the microcontroller, and the SPI (*Serial Peripheral Interface*) bus which is implemented by a connection MSSP (*Master Synchronous Serial Port*) of the microcontroller.

Three scenarios thus appear:

- The FM device is directly usable through RS232. That means that the device directly transmits the binary data flow on the medium;
- The IEEE 802.15.4 module using the SPI bus requires to set or to read registers to configure and use the service of telecommunication;
- The GSM / GPRS modem is used in the same way as any wired modem. The RS232 connection allows the use of the applications implemented on the device through "AT" commands like a classic PSTN modem.

B. *Signaling and communication protocols*

Each module studied in section A has specific communication and signaling services which can be extremely basic or may include complex embedded applications. The implementation of these services also differs a lot from one device to another. To develop the application of remote monitoring, students must initially understand the interest of these services, and then extend them if necessary. The following of this section details various aspects of the standard communication services offered by each module.

1) *Half-duplex FSK/FM 433MHZ device*

The FM 433MHz transmitter only offers a simple service to access the medium. It offers none of the classic services usually present on communication networks (based on the TCP/IP protocol stack for example) initially known by students during lectures about Internet basics: there is no addressing map, neither cyclic redundancy check, nor frame sequence number… The offered service is assimilated to a "simple" *broadcast* of data without other functionalities.

The student wishing to transmit information should follow the procedure below:

- Set the line TX of transmission;
- Write information on the microcontroller USART connection;
- Release the line TX of the device.

The instrumentation of this device is very easy; it is also possible to check a frame structure by capturing the RS232 frame with oscilloscope, both in sending and receiving modes.

This communication service is thus extremely simple to use (but also poor in functionality!); however students have to understand the need to release the line TX at the end of transmission if several transmitters alternately want to transmit (otherwise the receiver is unable to receive the data of transmitters emitting simultaneously).

This device is commonly and frequently used in the industry because of its low consumption and of its moderate cost. There are a lot of wireless sensor systems based on this technology; the most widespread examples are for home automation or for weather stations using wireless sensors. In spite of the simplicity of the services and the poor qualities of transmission offered by these devices, they offer a real interest in this lecture, essentially for two reasons. The first one is that the students have to ascertain that at a given moment, the risk of collision between two frames resulting from various sensors is unavoidable and even increases, obviously, with the quantity of simultaneous traffic. The second reason to study this device is related to the lack of reliability of this connection due to this risk of collision, but also to the loss of the signal quality when the receiver is far away from the transmitters or when it is not in direct vision.

Then, if it is required by the application, students have to consider additional mechanisms to make the connection reliable. Three solutions, that have different effects, can thus be envisaged:

- Set up a mechanism of detection and resumption of error;
- Make systematic redundancies of information, for example transmit the same frame several times to decrease the risk of collision and so decrease the risk of loosing a piece of information;
- Set up a mechanism of emission coupled with a mechanism of acknowledgement of the data that have been effectively received by the receiver.

The study of advantages and drawbacks of these solutions goes beyond the framework of this paper. However, the main consequence of the third solution is that the transmitter must also be able to receive data (to process acknowledgement)!

2) *IEEE 802.15.4 device*

The IEEE 802.15.4 device offers all the services defined in the 802.15.4 standard [9] via a *ZigBee* [10] stack. These services concern as well the communication and signaling protocols.

From the communication point of view, the device offers OSI/Transport level services, for example:

- The establishment of connection;
- The management of acknowledgments;
- The automatic retransmission mechanisms if data are lost…

There is also an advanced medium access control service which avoids the transmission of data through an already busy channel. The hardware offers various transmission channels; this allows a more accurate management of the bandwidth and reduces the risk of collision.

From the signaling point of view, *ZigBee* integrates many configurations of network topology: star, tree or mesh. For each of these topologies, it defines specific equipments, coordinator, and router in charge of the signaling mapping. To optimize the space memory on a microcontroller, *ZigBee* envisages a partial establishment of the signaling stack according to the targeted device. In this lecture, all the devices implement the totality of the *ZigBee* services.

From the student point of view, it is important to understand the interest of these services when the network topology becomes more and more complex. Indeed, *ZibBee* offers a management of the helpful services when the application targets aggregated traffics by data resulting from various sites. Services also offer a management of the communications (indifferently *unicast* or *multicast*) implying the crossing of several equipments: i.e. multi hop communications. The configuration of nodes, when an equipment fails or when the topology changes, is automatic if the appropriate services are activated. Fig.2 illustrates these various cases.

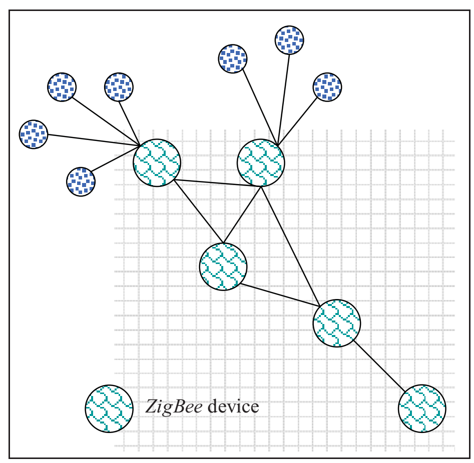

Figure 2. *ZigBee* suitable topology

3) *GSM/GPRS device*

The services offered by the GSM/GPRS device are different from those offered by the previous devices. They are more oriented towards embedded applications (voice, text, data, picture, video, music). From the user point of view, services like configuration of a topology, management of collision, etc. are hidden … If the appearance of these telecommunication devices may be seen out of the lecture scope, they are nevertheless very interesting. Indeed, the GSM remains a widely spread mean to transfer all kinds of information between an equipment with strong mobility and information server (typically “machines to machines”, *m2m*, applications) or a user. The parameter analysis on a vehicle fleet (position sensor, consumption measurement) is an industrial example. To keep a communication link between the sensor network and a mobile remote user, the students set up an application of SMS processing. This application allows to make the reporting of periodic events towards the user or to process a specific request of the user wishing to interact with the remote monitoring system (system deactivation, state of a sensor request…).

IV. STUDENT EVOLUTION

Students of Master 2 have to set up a prototype of a sensor network. They use this network to formulate generic principles on the wireless sensor networks: choice of a telecommunication device, communication and signaling protocols suited to a targeted application. This training includes 7 supervised sessions of practical works (3 hours each); free sessions are also scheduled so that the students can have access to the technical equipment.

The starting point is the application specifications. Various items are available: software development tools, sensors (this teaching is synchronized with another one which objective is the development by the students of all the electronic part of the sensors), microcontroller evaluation boards and devices, with a detailed technical documentation and datasheets. The interface boards between evaluation board and the three telecommunication modules are also given from the start.

Students have to discover and understand the manipulation of each device taken separately before starting to completely implement the platform.

The students have to follow the following evolution:

- Step 1: discovery of devices. For that purpose, they test every device by establishing a direct and basic communication (send of an *ASCII* characters) between a single transmitter and a receiver. This step is common to every device and requires no elaborated configuration nor to add services to those already offered by modules.
- Step 2: several transmitters on the network. By testing services offered by the first device (FM technology), students understand that it is necessary to add a field "address" in any emission of information. They also note a risk of collision and loss of frames which grows with the transmitter number if they do not use a device offering suitable services or if they do not extend those basic ones proposed by the device.
- Step 3: the network spreads out. The initial range of the first two modules (FM and *ZigBee*) is not sufficient to cover communication needs on more important distances. It is then essential to set up several modules with a suitable signaling service on intermediate devices.

Gradually, the students thus take into account a more and more complex topology until they consider the complete platform of test compatible with the application of remote monitoring. The objective for the students is to refine and to complete the information contained in the Table 1 by means of a platform whose technological solution is represented in Fig. 3. Indeed, this solution appears as the best compromise if all the parameters are taken into account. Effectively, if the criteria of cost and energy saving are ignored, the platform could consist only of sensors equipped with a GSM device allowing to cover all the needs of the application. On the other hand, as long as we only consider communications inside one site, a solution based on FM device could appear as sufficient. But this solution would require a very heavy development to guarantee the same flexibility of use and the same level of services offered by *ZigBee* device when the topology becomes complex.

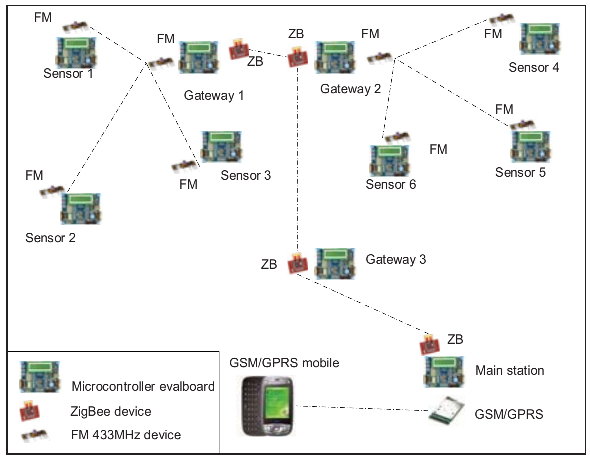

Figure 3. Platform solution

V. CONCLUSION

This paper describes a teaching experiment that addresses Master 2 students of INSA Toulouse. The scientific objective is the study of communication and signaling protocols involved in wireless sensor networks. In this course, students have to cope with a problem for which initially they don’t have any technological solution; they only possess the necessary general background. They must develop and experiment an appropriate study based on tests. To make these tests possible, the students set up a platform prototype based on various telecommunication devices. This platform answers a typical application of industrial site remote monitoring by the means of wireless sensor networks. The experience is conclusive, it demonstrates that even if Master 2 students have no specific knowledge in the field of the personal area networks, a scientific approach based on tests and analysis allows discovering generic principles.

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Deep Drawing Tool for E-learning

A didactic approach for manufacturing engineering education

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***Abstract*— Manufacturing processes are an important element in industrial engineering education. In distance education, the learning of engineering subjects has a special difficulty, which can be reduced by means of the use of new technologies, and the practice of mixed models of learning. One of these processes is the deep drawing due to its relevance in the industry. This paper presents a deep drawing tool for e-learning. The tool has been realized for its use in the Master degree because it requires advanced knowledge in manufacturing processes. The instrument has been developed with the objective of the students who can: a) Select input data for get the formability of material to deep drawing; b) Select the process that provides the best solution from a technological perspective; c) Optimize the process for saving the material; d) Know the influence of the punch in the results; e) Consideration of the process cost. The structure of the system has three subsystems: a) Solve, module for data processing and the generation of results; b) Materials, module for management data of the system; and c) Interface, module for user interaction. The tool has been implemented in the software tool programming, developed in Java. This language has been selected because it provides a methodology of object-oriented programming and its execution is possible in multiple operating systems. The paper describes each step of the tool, from the input data to final analysis and they are shown through the results given by the tool.**

Keywords-component; engineering education; manufacturing; manufacturing data processing; manufacturing planning; computer aided engineering formatting.

I. INTRODUCTION

Manufacturing processes are an important element in industrial engineering education. In distance education, the learning of engineering subjects has a special difficulty, which can be reduced by means of the use of new technologies, and the practice of mixed models of learning [1]. One of these processes is the deep drawing due to its relevance in the industry [2]. This paper presents the development of a didactic computer tool created by the authors for the resolution of multi-stage deep drawing industrial processes. Thus, the tool has been realized for its use in the Master degree because it requires advanced knowledge in manufacturing processes. Although there are some software applications about the deep-drawing optimization, this one allows analyzing technological and economical constrains and it permits minimizing the total process time, from a global perspective. The model provides a comprehensive analysis occurring in multi-stage processes of axi-symmetric geometry work-pieces [3-5]. The scientific model is established from the Leu [6] and Sonis et al. [7] works that provides LDR (limiting drawing ratio) solutions based on normal anisotropy value, strain hardening exponent and others, applied to the drawing and redrawing stages. The authors extend this work to the ironing stages, and provide a global and integral science solution for the total process [8-9]. The model permits to modify and correct certain process variables in order to predict the impact of those that are not fully controllable. It is based on defining a set of boundary conditions of the process for determining a range within which it is stable. The simultaneous accomplishment of the boundary conditions involved in each process (deep drawing, redrawing and ironing) permits to limit a range of values that define each stage of the total process [10-11] (see Fig. 1).

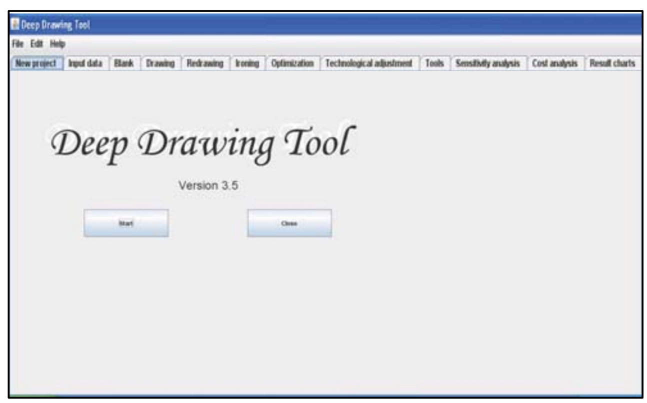


Figure 1. Main screen of the computer tool

Based on the technological model formulated, this paper presents a software tool created to implement the Aided System in a practical way. The computer tool was generated in a Java environment by creating a user-friendly interface and easy in its operation. The methodology has been the spiral model, software development model of evolution in which the software is realized in a series of incremental versions. This paper describes the tool constructed in their requirements, development methodology and structure. Finally, applies to the resolution of a case study, with the resolution screens that provides the Assisted System.

II. System Requirements

The system must comply several needs and characteristics of high-level of the developed system. The system must:

- Be independent of particular operating system. This should run on any system available in the market.
- Show the calculation results in a reduced time allowing easy interaction between user and system.
- Have a simple, clear and easy operation.

The interface design must meet the following general principles: a) Ease of learning: the user does not need much training time to use the interface; b) Consistency: all mechanisms of the interface are always used in the same way and thus produce the same result; and c) Flexibility: allow user interaction to drive the system through messages indicating everything that happens during the interaction.

The application consists of three parts:

- Calculation Module for data processing and generation of results.
- Materials: Module for the management of various materials that the system works.
- Interface Module intended for user interaction.

III. Methodology

The spiral model is a model of evolutionary software development where software is developed in a series of incremental versions. In the initial approach the incremental release might be a paper model or prototype as they are already performing approaches are achieved in more complete versions of the system. This model is suited to create products with different versions, improving with each approach, the current version and adding new functionality. Engineering can be developed through classical life cycle model or prototype construction. This methodology will, in each cycle, review the specifications of objects based on knowledge that is acquired with the operation of the aided system.

The spiral model is divided into regions of structural activities or tasks. There are generally three to six areas of work. These task areas are listed below:

- Customer communication: It includes the tasks necessary to obtain customer requirements. In this case a customer does not exist as such; the requirements are obtained from the project definition.
- Planning: Contains the tasks required to prepare the project, define resources and estimate the development time.
- Risk analysis: It includes the tasks required to assess technical risk and project-related tasks.
- Engineering: Contains the tasks required to set the system to be developed.
- Construction and adaptation: It contains the tasks required to build, test, install and provide user support.
- Customer Review: It includes the tasks required for the degree of customer satisfaction with the developed system.

When the evolutionary process starts, the software engineering team revolves around the spiral in clockwise direction, starting from the center. The first circuit of the spiral causes the development of a product specification; the following steps on the spiral could be used to develop a prototype and progressively more sophisticated versions of the software. Each step of the planning region produces adjustments in the project plan. Accordingly, the cost and the planning are adjusted by the reaction to the evolution of the client.

The spiral model can be adapted and applied throughout the life of the software. As the software evolves and the process progresses, the developer and the client understand and react to risks at each evolutionary level. This model allows the developers to apply the prototyping approach at any stage of product evolution. It will consider technical risks at all stages of development and reduce them before they compromise the project's development.

IV. Structure of the System

The purpose of this section is to describe the structure of the system, which has three packages that define it.

Each one of these packages corresponds to a module defined in the system.

- Calculation Package: Package that implements the functions of data processing and delivery of outcomes.
- Material Package: Package that implements the management functions of the several materials that the system works.
- GUI Package: Package that implements the user interface.

Each of these packages in turn contains classes that implement the functionality itself.

V. Development of the Computer Tool

The purpose of this section is to define the precise nature of the development system used.

Since the system must be compatible with different operating systems in the market, we have selected Java as development language. Java is a language of object-oriented programming developed by Sun Microsystems in the early 90s. The Java language was created with five main objectives:

- It should use the methodology of object-oriented programming.

- It should allow the execution of a program on multiple operating systems.
- It should include default support for networking.
- It should be designed to execute code on remote systems securely.
- It should be easy to use and take the best from other object oriented languages like C + +.

Note that Sun Microsystems released the bulk of their Java technologies under the GNU GPL, according to the specifications of the Java Community Process, so that virtually all of Sun Java is now free software. To facilitate the development and purifying, the system will use a modular development system.

Modular programming can be defined as one that addresses the solution of a problem by breaking it down into simpler sub-problems, each of which is solved using an algorithm or module more or less independent of the rest (hence the name "modular programming"). The advantages of modular programming are several: facilitates the understanding and resolution step; increases the clarity and readability of programs; allows multiple programmers working on the same problem at a time, since each one can work in one or more modules quite independently; reduce development time, reusing previously developed modules; improving the reliability of programs, it is easier to design and debug small modules than huge programs; and finally facilitates the software maintenance.

Moreover, we can safely say that it is virtually impossible to write a large program if we do not proceed to divide it into smaller chunks, covered by our poor human intellect. In general, the main problem is solved on an algorithm which we call algorithm or core module, while the simple sub problems are solved in sub-algorithms, also called modules. Sub-algorithms are subordinate to the main algorithm, so it is what decides in which order it should be implemented and how the sub-algorithms dataset. The main algorithm makes calls or invocations to sub-algorithms, while these return results to the former. Thus, the main algorithm is collecting all the results and it can generate the solution to the global problem.

VI. APPLICATION TO A CASE STUDY

This section shows the resolution of a case study developed by the Aided System. As input data following the dimensions of the piece that we want to obtain:

- External diameter $d_n = 150$ mm
- Length $l_n = 600$ mm
- Bottom thickness $s_n = 4$ mm
- Wall thickness $e_n = 1$ mm
- Material type UNS A95182.

A. New Project

Once implemented the program shows the startup screen. We will begin to work with the tool clicking on the START button (Fig. 1). If we click CLOSE the application will be closed. This screen also indicates the application title "Deep Drawing Tool" and the version we're using, in this case 3.5. From the home screen we can access at any stage after having run through the dialogs above, showing the titles of the corresponding phases.

B. Input Data

The input data are entered on screen "INPUT DATA" (Fig. 2), which indicates the size and type of piece we want to get. The dialog asks us about several data concerning the external diameter, length, bottom and wall thickness.

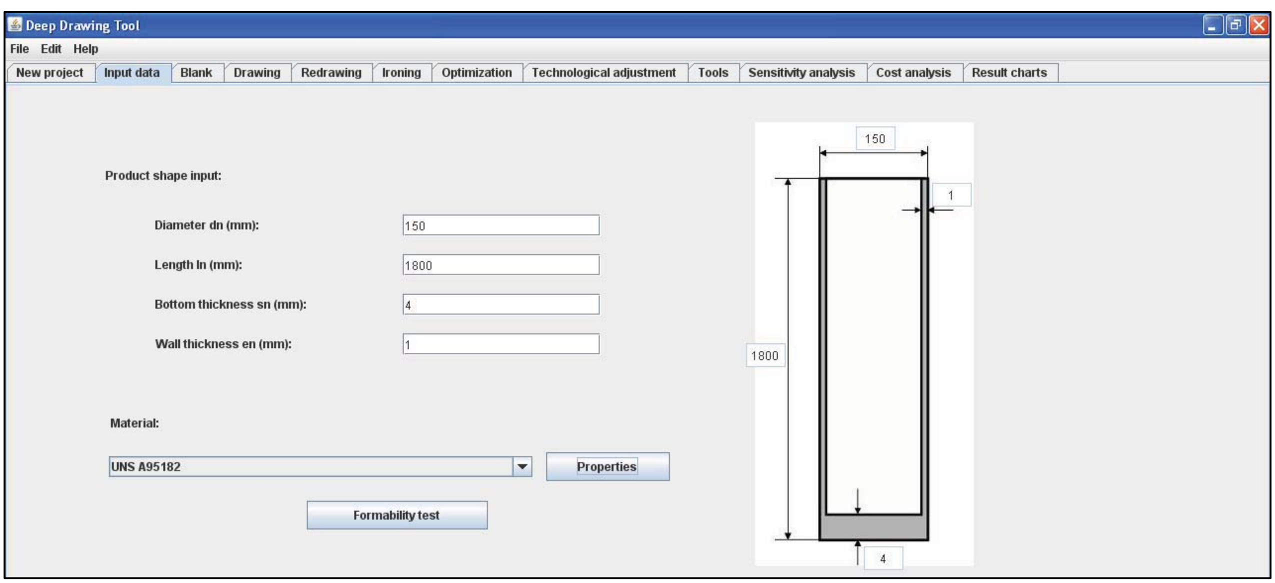


Figure 2. Input Data Screen

We must also choose the type of material in which we want to make the piece, with a choice between several options. In this version of the program we have selected three materials: UNS C26000 brass, UNS G10080 steel and UNS A95182 aluminum. For the present case we have selected UNS A95182 aluminum. Clicking on the PROPERTIES button it will be open a window informing us about the characteristics of the selected material (Fig. 3).

Figure 3. Material Properties Screen

By pressing the button "SOLVE" we can obtain the dimensions of the blank: diameter and thickness.

C. Blank Dimensions

The second step of the application is the study of the blank dimensions. The application displays the screen for determining the dimensions of the disc or BLANK (Fig. 4). For information purposes, this screen shows the data corresponding to the final dimensions the piece will have and the type of material chosen.

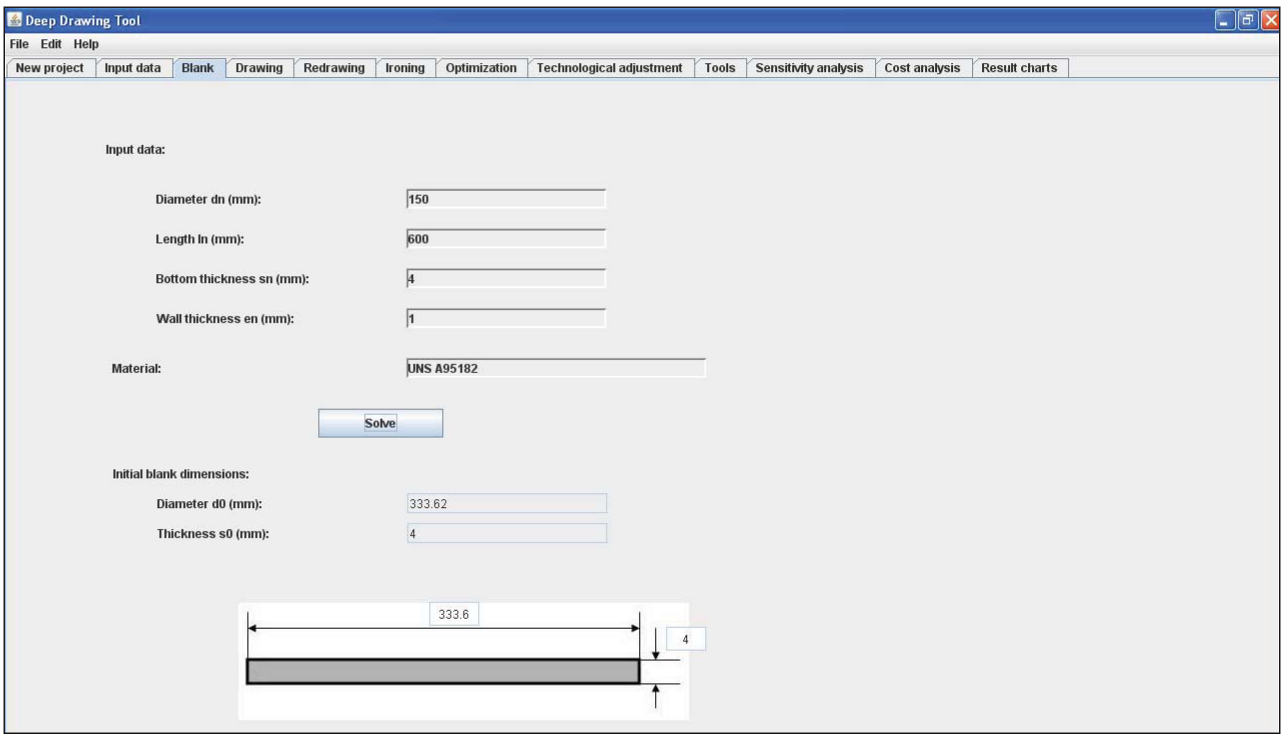


Figure 4. Blank Dimensions Screen

D. Drawing

The size of the disk obtained starting the program solves the first phase of the process of drawing or DEEP DRAWING, through the screen shown in Fig. 5.

The input data are those relating to blank diameter, thickness and diameter of the punch-stretching phase. It is important to show here the value of this diameter d_p because it will condition the design of this phase. It may be that the boundary conditions at this stage of drawing are to obtain a diameter smaller than the diameter of the punch inside the piece that we want to manufacture, an issue that limits the calculation at this stage [12].

The application requires the introduction of the value for efficiency coefficients in the two boundary conditions defined. The remaining input values are shown for information, since the application's taken directly from the database, depending on the type of material selected. SOLVE pressing the program calculates the drawing stage called Stage 1.1, providing the necessary data regarding the diameter of the stuffing, length, thickness, diameter of the punch, drawing ratios and thickness reduction, and maximum force applied during the process drawing.

Once it defines the drawing phase, the program performs the audit of the experimental conditions of drawing, for information.

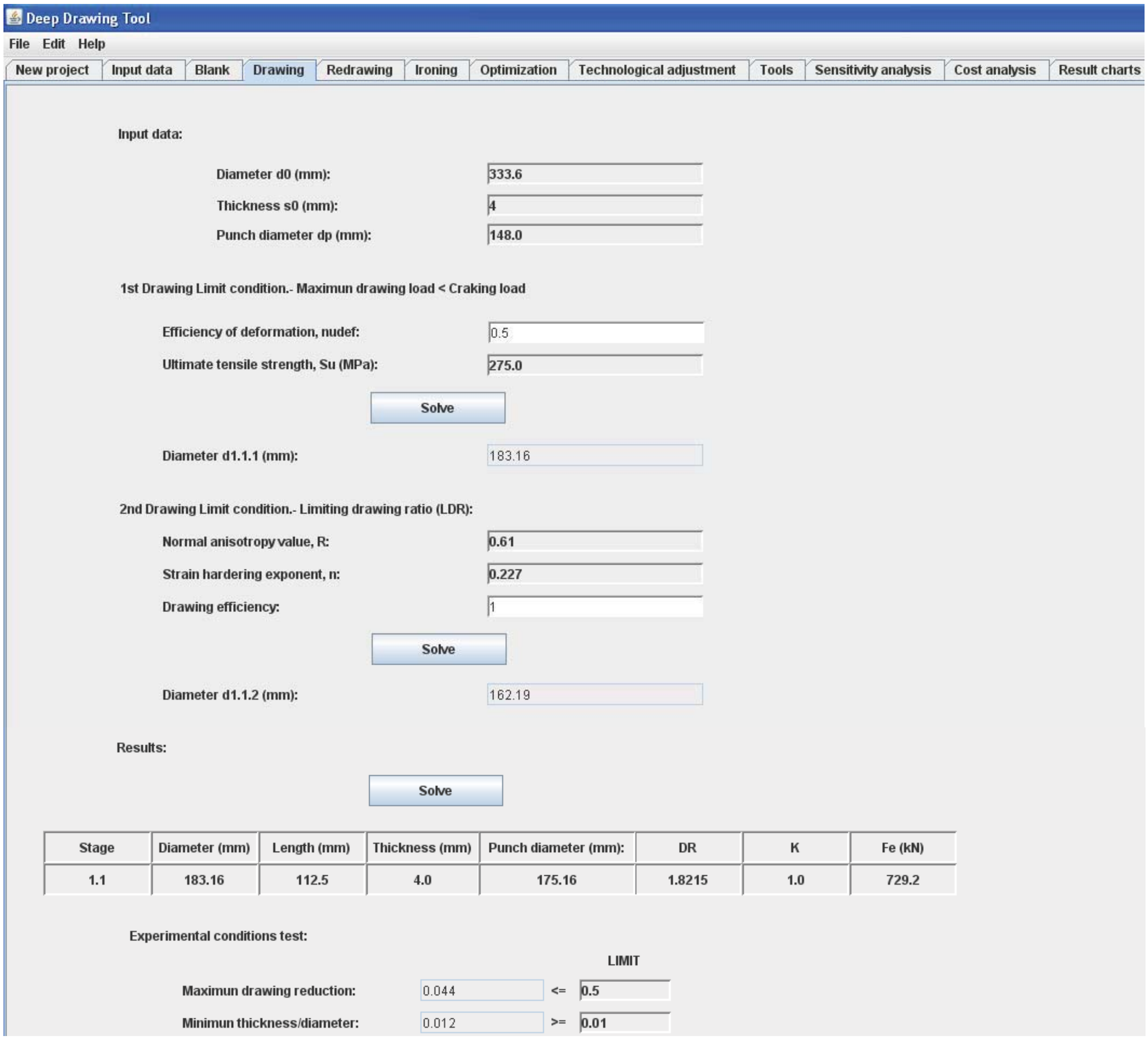


Figure 5. Drawing screen

E. *Redrawing*

The next phase of the process resolves redrawing or redrawing operations. From the dimensions obtained in the previous phase, embossing, which were provided as input, the program models at this stage on three boundary conditions (Fig. 6). In the first condition it is necessary to introduce limit values for the coefficient of friction, angle of the matrix and the radius die. The second boundary condition requires the application to provide the data for the efficiency factor and the value of the initial deformation [13]. The third condition is resolved based on the information that counts and that the application has already been introduced earlier. SOLVE proceed by pressing the calculation of phases for the process redrawing from 1.2 to Stage 1.n. It may be that it only requires a redrawing phase, as in the case presented, or even none.

In the event that, by the geometry of the piece to model, we evaluated in the case that it is not necessary redrawing stages, the program will provide a message that this case does not require redrawing phases.

The resolution redrawing process provides the results for the diameter of the stages, length, thickness, diameter of the punch, redrawing ratios, maximum force exerted at each stage and radio redrawing entry in the matrix for each phase.

The application also provides the results for Phase 1.m is that stage at which we could have come with redrawing process if the final dimensions of the piece had not limited the process. Redrawing, when the process is conducted in three stages over this "surplus ratio" in redrawing process is used to optimize the corresponding phases.

F. *Ironing*

The next phase of the model for the drawing process is solved by the application of three drawing boundary conditions (Fig. 7). The first boundary condition is solved in a straightforward way by applying the data for the material and geometry of the last stage of the process of redrawing. In the second boundary condition requires the application to provide the data for the efficiency factor and the value of the initial deformation. The third condition corresponding to the maximum ratio of wall thickness reduction is resolved based on the information that counts and that the application has already been introduced earlier. SOLVE proceed by pressing the calculation of phases for the drawing process, from Stage 2 to Stage n. It may be that it only requires a drawing phase, or even none will be necessary.

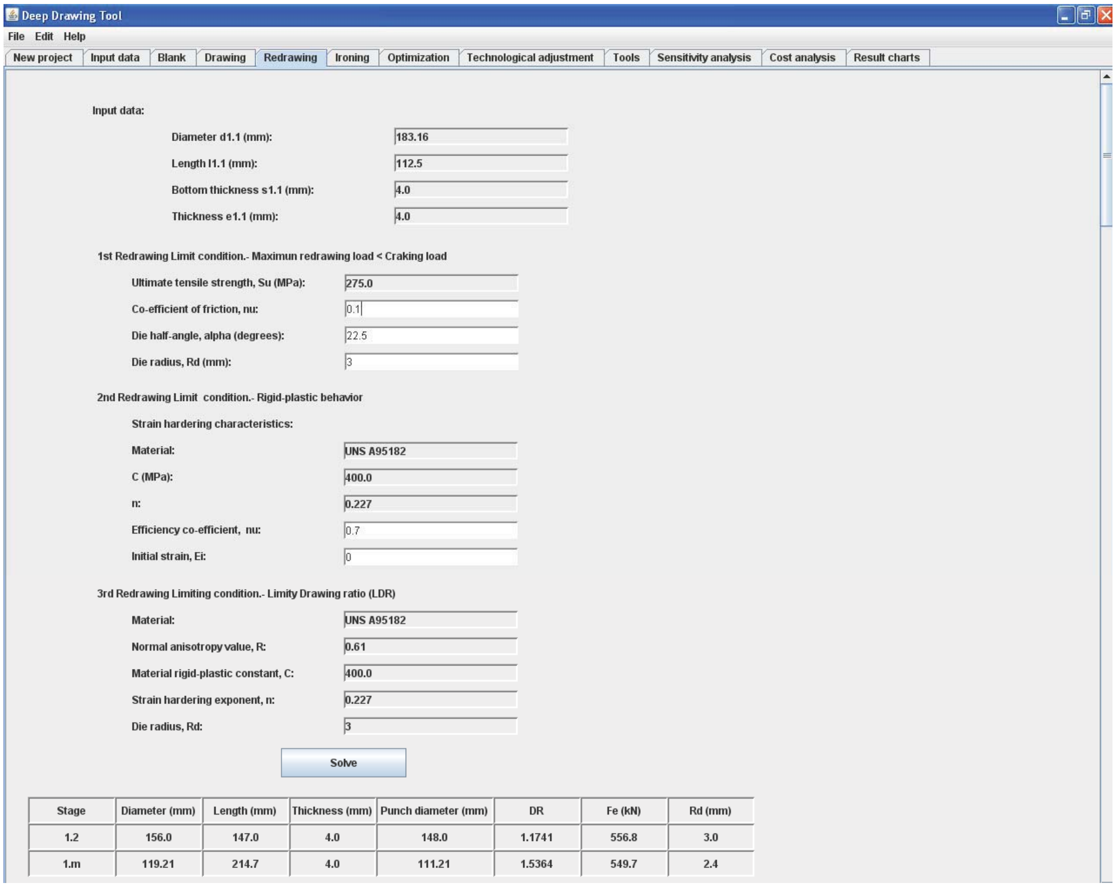


Figure 6. Redrawing screen

G. *Process Optimization*

Once provided the initial solution, the model is an optimization process in a comprehensive manner for redrawing and ironing operations (Fig. 8).

As input ratios appear stretched redrawing and surpluses in the last stage of each process. The model solves the optimization based on the definition of the number of times that it is necessary to split the surplus ratio (x_{re} for redrawing and x_e process for the drawing process), and operating parameters of the machinery involved in every stage of process [14-16].

Before proceeding to calculate the optimization process it is necessary to set the operating parameters of the machinery, for which the system will ask for entering the machinery used in each stage:

- Approach velocity
- Operation velocity
- Recovery velocity
- Tool total length

These data are entered via the dialog screen shown in Fig. 8. After entering the operating parameters of the machine, pressing SOLVE it proceed to the calculation of the optimization process, the following output shown in Fig. 9.

The results are the outcomes for each phase, optimized processes and redrawing stretched, diameter, length, thickness, drawing ratio, ratio of wall thickness reduction, drawing maximum power and operating time.

H. *Technological Adjustment*

The model allows adjustment technology by defining a clearance that increases the diameter of the hallmarks of the stages of drawing. Defined this clearance, the model automatically recalculates the entire process and provides a solution "adjusted" for the entire process: drawing, redrawing and ironing (Fig. 10).

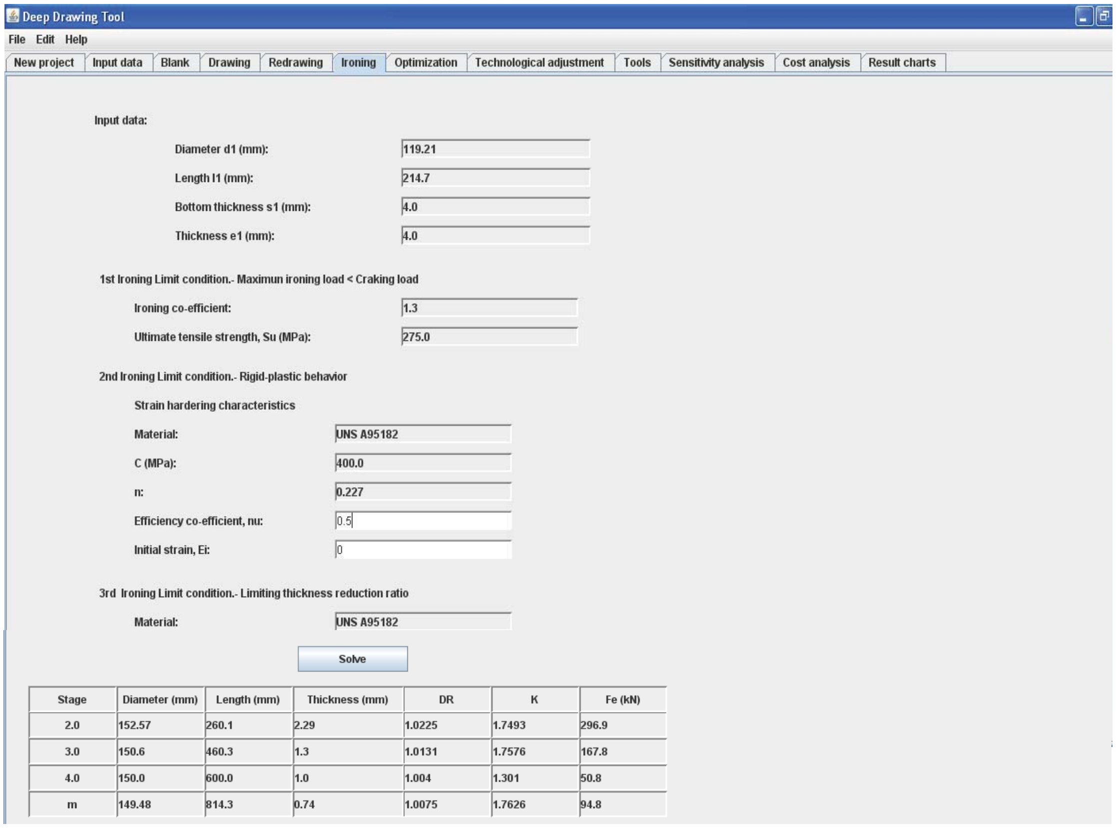


Figure 7. Ironing screen

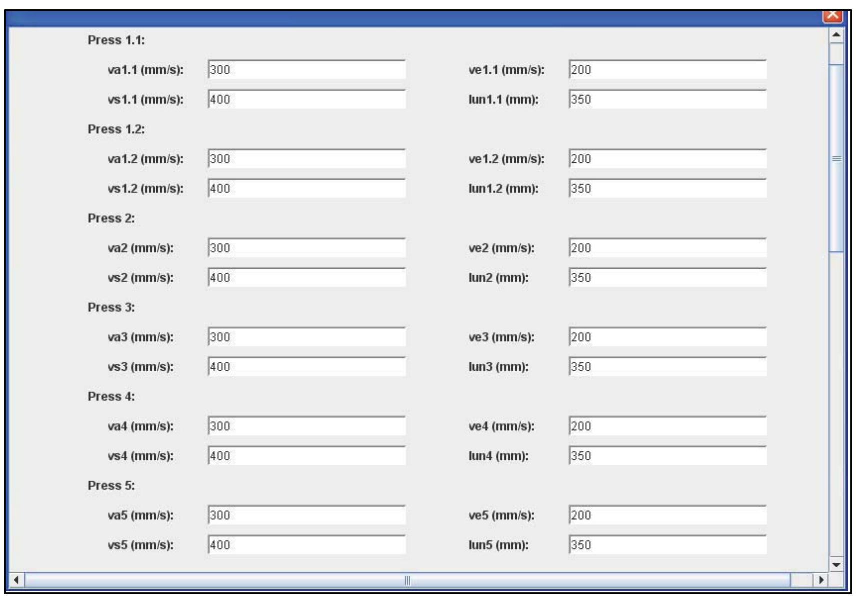
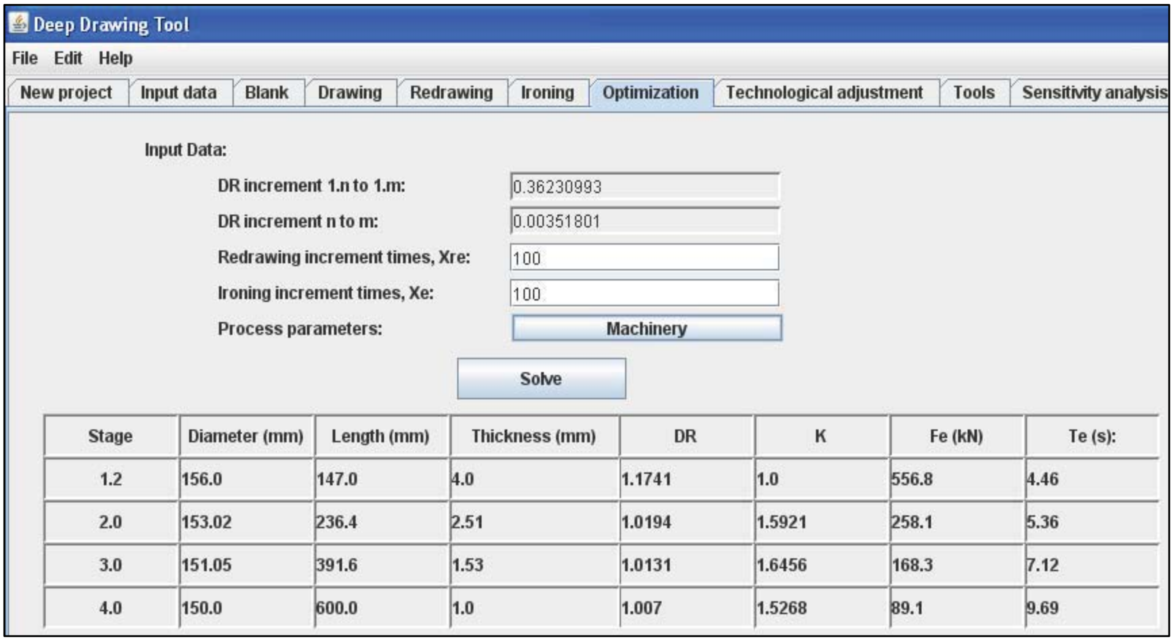


Figure 8. Machinery parameters

I. *Sensitivity Analysis*

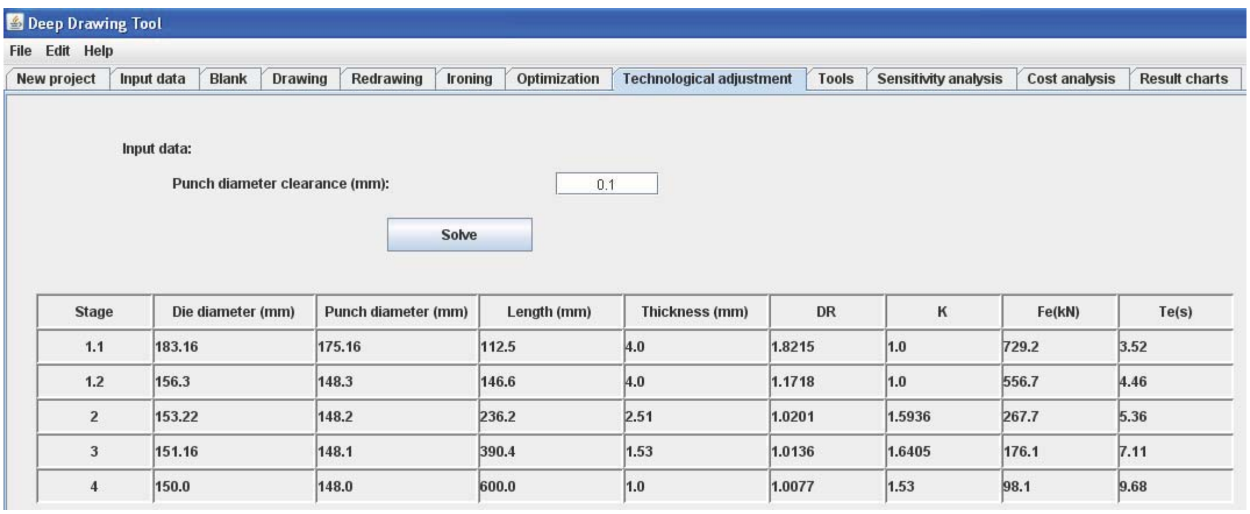
In the next phase, the process carries out a sensitivity analysis to the weathering of parent involvement in the process.

We define the diameter limit for each stage which can progress to the wear of the dies without endangering the stability of the process. Having established the limiting diameter setting a check is made as the diameter of the stage corresponds to the limit calculated (Fig. 11).



Stage	Diameter (mm)	Length (mm)	Thickness (mm)	DR	K	Fe (kN)	Te (s):
1.2	156.0	147.0	4.0	1.1741	1.0	556.8	4.46
2.0	153.02	236.4	2.51	1.0194	1.5921	258.1	5.36
3.0	151.05	391.6	1.53	1.0131	1.6456	168.3	7.12
4.0	150.0	600.0	1.0	1.007	1.5268	89.1	9.69

Figure 9. Optimization Process Screen



Stage	Die diameter (mm)	Punch diameter (mm)	Length (mm)	Thickness (mm)	DR	K	Fe(kN)	Te(s)
1.1	183.16	175.16	112.5	4.0	1.8215	1.0	729.2	3.52
1.2	156.3	148.3	146.6	4.0	1.1718	1.0	556.7	4.46
2	153.22	148.2	236.2	2.51	1.0201	1.5936	267.7	5.36
3	151.16	148.1	390.4	1.53	1.0136	1.6405	176.1	7.11
4	150.0	148.0	600.0	1.0	1.0077	1.53	98.1	9.68

Figure 10. Technological Adjustment Screen

J. Cost Analysis

In this phase of the system evaluated the costs involved in the whole process by introducing the input data for the total number of units to manufacture, raw material costs, hourly cost of labor and cost of electricity. The model provides the total costs for different solutions: initial, optimized and technological adjustment (Fig. 12).

K. Results

Finally, the model shows the graphs of results showing the evolution of certain variables over the entire process and showing a comparative for the solutions provided: initial, optimized and technological adjustment.

The graphics are as follows:

- Drawing Load vs Stage........................ Fig. 13
- Drawing Ratio vs Stage……………… Fig. 14
- K coefficient vs Stage……………… Fig. 15
- Length vs Stage……………………… Fig. 16
- Process total time…………………… Fig. 17

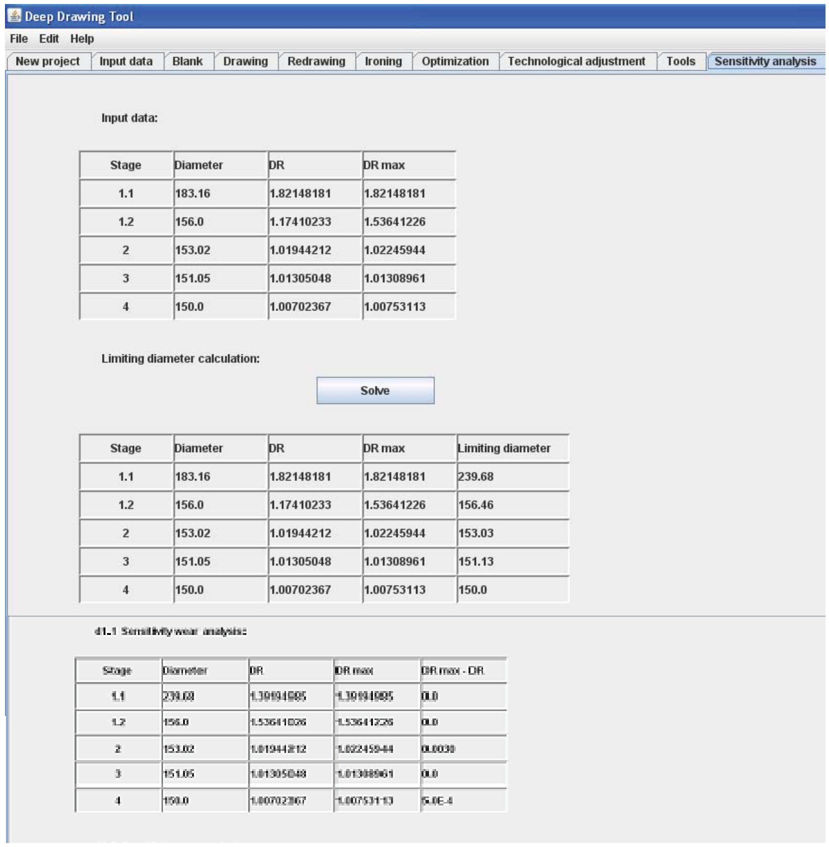


Figure 11. Sensitivity Analysis Screen

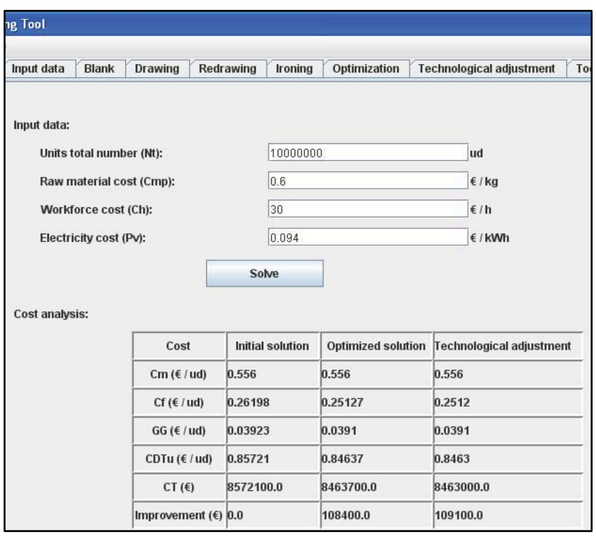


Figure 12. Costs Analysis Screen

CONCLUSIONS

This paper has summarized the functions of a deep drawing tool for engineering education. The tool allows selecting input data for getting the formability of material to deep drawing, selecting the process that provides the best solution from a technological perspective, optimizing the process for saving the material, knowing the influence of the punch in the results and considering the process cost.

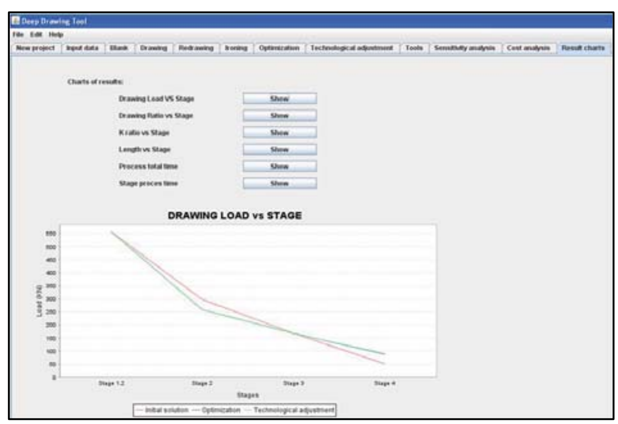


Figure 13. Graphic “Drawing Load vs Stage”

The structure of the system has three subsystems: Solve, module for data processing and the generation of results; Materials, module for management data of the system; and Interface, module for user interaction. The tool has been implemented in software tool programming, developed in Java. The paper describes each step of the tool, from the input data to final analysis and they are shown through the results given by the tool.

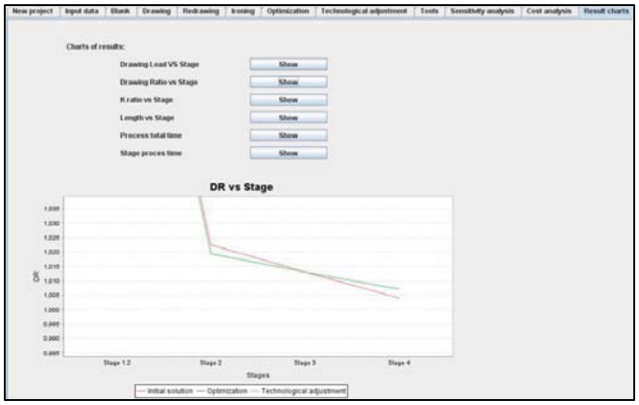


Figure 14. Graphic "DR vs Stage"

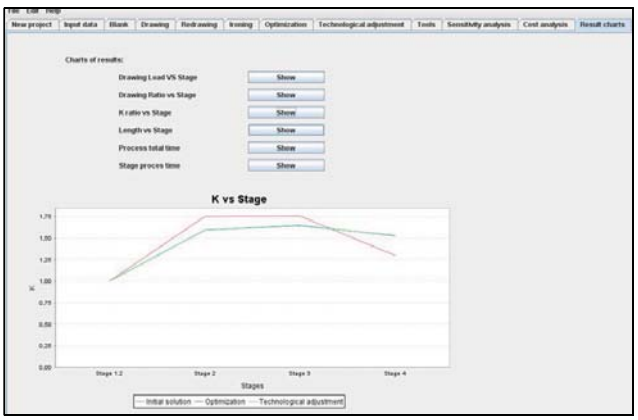


Figure 15. Graphic "K Coefficient vs Stage"

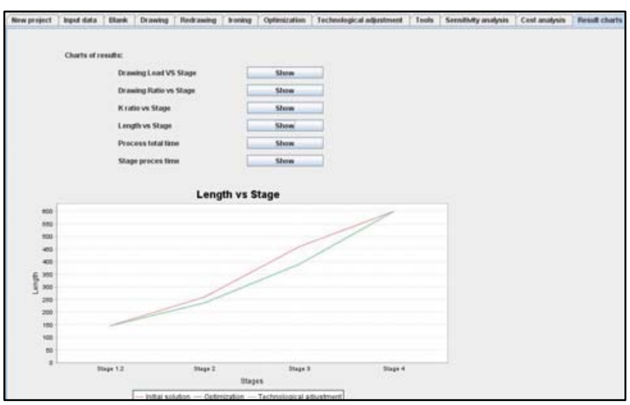


Figure 16. Graphic "Length vs Stage"

Future works, in this field, will go towards to implementation of the tool, and accordingly to the results, some improvements will be carried out.

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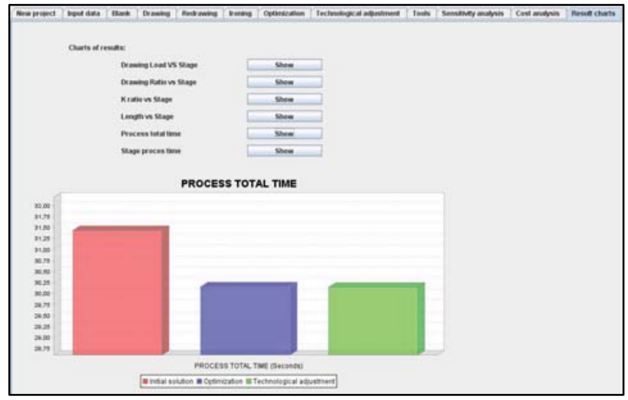

Figure 17. Graphic "Process total time"

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A review of electronic engineering design free software tools

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Abstract— **In this paper, we review electronic design free software tools. We have searched open source programs that help with several tasks of the electronic design flow: analog and digital simulation, schematic capture, printed circuit board design and hardware description language compilation and simulation. Using some rapid criteria for verifying their availability, we have selected some of them which are worth working with. This work intends to perform a deeper analysis of free software tools and select some of them to use in education or in professional electronic design.**

Keywords- electronic design; free software;quality; evaluation.

I. INTRODUCTION

Free software is an increasing phenomenon that has attracted a lot of attention in academia, industry and among end-users. Following the definition of the Free Software Foundation (FSF) [1], free software concerns the users' freedom to run, copy, distribute, study, change and improve the software. Beyond its philosophical principles, the way many free software projects are developed, often against traditional software engineering practices, is also a research topic [2].

The interest in free software would not have increased without the success of many projects that are widely used and accepted [3]. GNULinux and the Apache web server are probably the most well known, but there are many others: user applications (e.g., GIMP, OpenOffice), programming languages (e.g., Perl, Python), internet resources (e.g., sendmail, bind), adaptations to embedded systems (e.g., OpenMoko, Nokia 770). However, not all free software programs have reached a high quality level and open source repositories [4] show many abandoned projects.

Regarding electronic design, the following question arises: Which is the state of free software tools for electronic design? Are they useful? The long term goal of the present work is to answer these questions, evaluating the situation of these tools and selecting some of them for education or professional use. In this paper, we present a first review of such tools and perform a preliminary selection. We also point out the main weakness detected.

II. OUTLINE

The steps we have followed are outlined in Fig. 1:

- Search for free software tools: we have searched free software tools that help in typical tasks of the electronic design flow.
- Rapid test and program selection: we have performed a rapid evaluation of the programs found. This has allowed us to select some of them for a further research and deeper evaluation.
- Analysis of rejections and summary of selected programs.

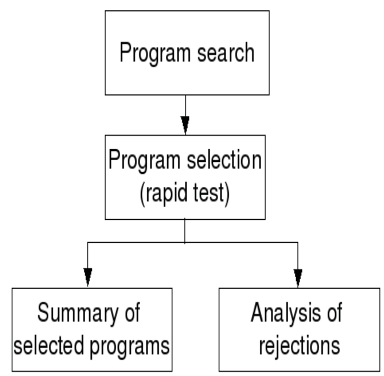

Figure 1. Main steps of the present work

III. SEARCH FOR FREE SOFTWARE TOOLS

A. Topics selected

We have searched for tools that are related to the following tasks:

- Analog simulation (AS): schematic capture with netlist generation, simulation engines and data visualization.
- Digital simulation (DS).
- Schematic capture (SC).
- Printed Circuit Board (PCB) Design.

- Hardware Description Language (HDL) design: compilation, simulation and waveform viewers.

B. Sources of information

We have searched in FSF [1], in classical repositories [4] and through the Internet using the Google Web search engine. Examples of keywords used are Electronic Design Automation (EDA), electrical, electronic, schematic capture, simulation, HDL, PCB, etc.

C. Programs found

In table I we have listed the number of programs found and the category they are included in. In some cases, they are divided into subcategories. In the analog simulation class, the sum of the programs in the subcategories does not equal the total in the category because there are integrated environments that belong to several subcategories at the same time.

TABLE I. NUMBER OF PROGRAMS FOUND AND THEIR CATEGORY

Category	**Number**	**Subcategory**	**Number**
Analog simulation (AS)	24	Simulation engine	9
		Schematic capture + netlist generation	10
		Data visualization	10
Digital simulation (DS)	13		
Schematic capture (SC)	22		
PCB design (PCB)	12		
HDL design (HDL)	28	Simulation and compilation	25
		Waveform viewer	3
Total	99		

IV. RAPID TEST OF PROGRAMS

Evaluation of software quality is still a controversial issue. There has been an evolution of this concept and the definition depends also on the perspective (architecture, source code, processes or community). ISO/IEC 9126 [5] offers a standard with six quality characteristic divided into several subcharacteristics. This quality model has to be adapted to every program. Other models focus on the free software world, analyzing their typical aspects: Open Business Readiness Ration, QSoS [6] and QualOSS [7]. However, applying those models to all the programs we have found is out of the scope of the present paper. We first have to pick up some of the software we have found. Thus, we have adopted a practical point of view and adopt the role of an electronic designer who wants to select a set of programs for further research. We have then specified five items in order to perform a rapid test.

- Is there a stable version?

A stable version would give confidence to software users. However, this question was not easy to answer. Traditionally release version 1.0 is the first one delivered to customers and considered stable. However, many free software projects follow the "release early, release often" rule [2], which means that the programs are available to the public well before they are considered stable. The Sourceforge repository includes information about the status of the software (alpha, beta or stable). But other downloadable programs have not this information. Therefore, this item was of limited use.

- Can it be easily installed?

If available, Windows versions usually pose no problem. For Linux users, probably the most interested in this kind of software, package management systems are the preferred way to install software because they solve all the dependencies. We have used the "aptitude" utility in the Kubuntu 8.01 distribution [8]. If no package is available, we have tried to compile the program from the source code and tried to solve the problems that appeared.

- Is the learnability good?

This is probably one of the most important points to attract new users. We have looked for user's manuals, "getting started" guides, wikis or web pages, examples etc. They should at least allow the user to start working with the tool.

- Can it work with a simple example?

We tried simple examples in order to check that the program is not only installed, but that can run simple simulations, draw simple schematics, etc. This is similar to the idea of the "hello world" program that can be found in many introductory tutorials of programming languages.

- Is it likely to be maintained in the future?

Any potential user should be interested in the project future and the probability that it will be debugged, improved, updated or extended. To answer this question, we paid attention to the frequency of new versions, the number of developers, the number of messages in mailing lists or the news that appeared in the corresponding sections.

The goal of this five item test is to determine whether or not it is worth evaluating the program in depth.

V. ANALYSIS OF REJECTIONS

In this section, we analyze the reasons that led us to reject many of the projects found. Table II summarizes the results. The terms used in the table together with further comments are explained in the next paragraphs.

TABLE II. MAIN REASONS TO REJECT PROGRAMS

Problem	**AS**	**DS**	**SC**	**PCB**	**HDL**	**Total**
Abandoned	8	4	13	6	8	39
Does not install	1	0	1	0	3	5
Poor learnability	3	3	2	0	1	9
Failure to work with simple examples	2	0	1	0	1	4
Other	3	3	1	3	7	17
Total	17	10	18	9	20	74

In the group of abandoned projects we have included projects that have had no activity (news, releases) for more than two years. In this group there are also projects that classify themselves as in ‘planning’ state. However, this state coincides with a lack of activity, at least in the cases we found. As can be deduced from the table, there is a high number of abandoned projects, a 53 % of the total of rejections. This is clearly a waste of effort. New developers should adhere one of the lesson of [2]: *“Good programmers know what to write. Great ones know what to rewrite (or reuse)”*.

With respect to the installation, many of the programs are available as Kubuntu packages, what makes the installation very easy. For the rest, source compilation is possible if the libraries it depends on are installed previously. We have been able to compile most programs successfully. A few of them showed compilation errors, such as undefined symbols, which prevented us from getting an executable.

There are not many programs that fail when dealing with simple examples like an RC circuit, HDL code with basic logic, etc. At least, the projects that are not abandoned and that can be installed are able to perform some operations.

Poor learnability is associated with a lack of documentation. Unfortunately, there are nine projects that are rejected mainly due to the poor documentation. In many cases they are hosted by attractive web pages, they are updated regularly and they can be installed without problems. But the section documentation is still under construction, or shows a similar message, so the newcomer hits the wall when trying to build up his own examples. From the user point of view, this is really disappointing. Electronic designers are not always programming experts and looking into the source code can be very hard.

The row entitled “Other” in table II accounts for other reasons to reject a program that are not in the previous categories. In some cases the programs are very basic, e.g. only a few gates in digital simulation, or they are oriented towards kinds of design not considered here, e.g. full custom design. There are also many examples of exotic approaches. For instance, programs that help to create modules for other tools, to debug or to write code. Integration of Spice-like simulation or hardware description with general purposes languages (Tcl, Ruby, Python) is a key point of several projects. Although they are remarkable efforts, we have stuck to the typical approaches to the electronic design topics considered in this paper.

We should mention that we have rejected two popular programs. Both of them are active and have been developed for many years. The first one is *Xcircuit* [9]. We could not make the examples work due to a segmentation fault. However this can be due to a packaging problem with Kubuntu and other Linux distributions should be tested. We could not compile the source code successfully either. The second one is *Alliance* [10], a set of CAD tools for VLSI design that includes a VHDL compiler and simulator. There is no package available in Kubuntu, and we also failed to compile the source code. This should be further researched.

VI. SELECTED PROGRAMS

The number of programs that we have selected is shown in table III .

TABLE III. SUMMARY OF NUMBER OF PROGRAMS SELECTED

Category	Programs selected	Total	%
Analog simulation	7	24	29
Digital simulation	3	13	23
Schematic capture	4	22	18
PCB design	3	12	25
HDL	8	28	29
Total	25	99	25

A. Analog simulation

We have found two motor simulations, *ngspice* [11] and *gnucap* [12]. They are both command line programs. *Ngspice* is based on the well-known Spice3 simulator originated at the University of California. Since 1999, its code has been bug-fixed, cleaned, ported to the GNU/Linux platform and improved with models and simulation options. *Gnucap* is the Gnu Circuit Analysis Package. It is not based on Spice and the engine is designed to do true mixed-mode simulation.

Gwave [13] and *Kjwaves* [14] are tools to view analog data from the output of simulations. *Gwave* is part of the gEDA toolkit. *Kjwaves* is written in Java and has a nice user interface.

Schematic programs that can output Spice netlists are also considered in this section. *Gschem* [13] is a graphical tool which is part of gEDA to facilitate the input of components. Once the schematic file and the required symbols are ready, they can be converted into netlists using the *gnetlist* [13] command. *Kicad* [15] is an open source program for the creation of electronic and schematic diagrams and printed circuit boards. It has an option for the creation of Spice netlists.

Finally, we have found an integrated environment which has its own flavour. It is called Quite Universal Circuit Simulator, *Qucs* [16]. It can simulate analog and digital circuits. It deviates from typical Spice-like simulators. The entry is graphical and the simulation itself can be seen as an embedded object in the main window, Fig. 2. The user documentation is very poor, but there are some specific tutorials that allow new users to run simple examples. Despite the documentation, we have kept this project as a valuable tool, due to its nice and intuitive graphical interface.

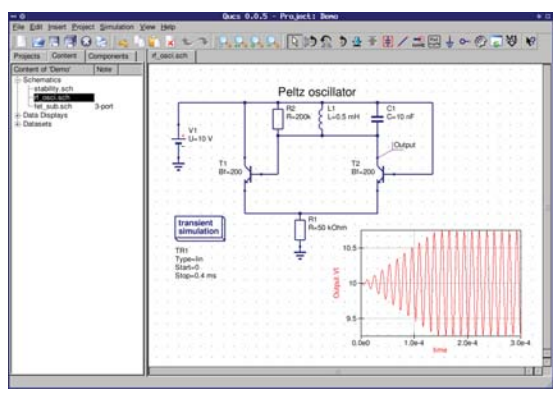

Figure 2. Screenshot of Qucs, taken from [16]

B. Digital simulation

Three projects gave us enough confidence in this section: *Tkgate* [17], *LogiSim* [18] and *Qucs*. *Tkgate* is an event driven digital circuit simulator with a tcl/tk-based graphical editor. It is a mature project that started at Carnegie Mellon University in 1987. *LogiSim* is written in Java and intends to be an educational tool for designing and simulating digital logic circuits. *Qucs* can not only perform analog simulation, as explained in the previous section, but also digital simulation. It is in fact based on the VHDL engine FreeHDL [19], but the user can simulate directly from a schematic entry without entering any VHDL code.

C. Schematic capture

Four programs have passed our rapid test. Three of them have already been reported in previous sections (*gschem, Kicad, Qucs*). The fourth one is *TinyCAD* [20]. It is a simple program that can print your diagrams or transform them into PNG images. It can be also used to output netlist for Spice or PCB programs. However, Spice output requires the introduction of many parameters by the user, which makes this process painful. In addition, only commercial PCB formats are possible as outputs, except for *FreePCB* (see next section).

D. PCB design

This is the category in which we have found fewer programs and as a consequence, fewer programs passed our rapid tests. This is probably due to the higher difficulty of the user interaction programming. The three programs are *PCB* [13], *FreePCB* [21] and *Kicad* [15]. *PCB* is now associated with the *gEDA* tool suite. Therefore, a schematic entry with *gschem* can be the first step of a printed circuit board design. The schematic file can be converted to a netlist compatible with *PCB* using the command *gnetlist*. *PCB* is a twenty year old application, which has been enhanced with Gerber generation, autorouter and GTK port. *FreePCB* was designed to be easy to use and ease to learn. It has only Windows version. In principle, netlist has to be entered semi-manually with a text editor. Since 2008, a utility written by a user allows converting *TinyCad* netlist into PADS-PCB netlists suitable for *FreePCB*. *Kicad* also allows the user to design a printed circuit board, starting from a schematic capture. All the steps of the design flow are integrated into a single graphical interface, much as the manner in which some commercial programs do.

E. HDL compilation, simulation and data visualization

We have found five compiler and simulator tools for HDLs. *Icarus* [13] is a command line verilog compiler, which is now associated with gEDA. In fact, there are two main commands: *iverilog*, which compiles the code, and *vvp*, which is the simulation run time engine. The ouptut of the simulation is a VCD file, but other waveform dumps are available. Typically, the user has to include a test bench within its program. *Ghdl* [22] acts in a similar manner, but with VHDL code. It is a command line compiler that can analyze or execute a design (test benches) depending on the flags used. In the latter case, VCD file format output is possible. *Veriwell* [23] is another command line verilog compiler which outputs VCD files. While last version is recent, documentation is worse than that of *ghdl* or *icarus*. *Signs* [24] can be used either as a command line or as an Eclipse plugin [25] for hardware design and simulation. At the moment, VHDL is the main language. Eclipse defines itself as an open development platform comprised of extensible frameworks, tools and runtimes for building, deploying and managing software across the lifecycle. It was hard to make it run the examples of the *Signs* tutorial, but this is probably due to our inexperience with the Eclipse environment. On the other hand, *Signs* has an integrated interface, Fig. 3, which is closer to commercial tools. The last compiler we have found is *freeHDL* [19]. Although the home web page has some characteristics of an abandoned project, such as empty pages and old documentation, it is the backend simulator used by *Qucs*, which is a quite active project. *Qucs* now accepts user written VHDL code in digital simulations. The results of a simulation are embedded as in Fig. 2.

Two waveform viewers are specific to digital simulation: *GTKwave* [26] and *Dinotrace* [27]. Both of them accept VCD and other file formats. *Dinotrace* comes with an interface to Emacs which allows source code and log files to be annotated with the values of signals.

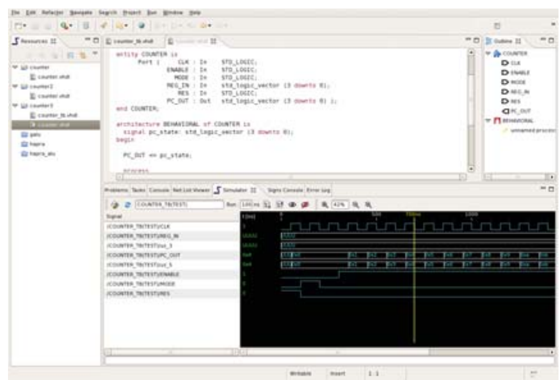

Figure 3. Screenshot of *Signs*, taken from [24]

VII. CONCLUSIONS AND FUTURE WORK

We have searched for free software tools that help in some tasks of the electronic design flow. Then, we have performed a rapid check and test of the programs in order to select which ones are worth continuing working with. We have found that about 39% of the projects are abandoned. On the positive side, we have found that there are several programs that cover each of the tasks considered in this study: analog simulation, digital simulation, schematic capture, PCB design and HDL design. Thus, we think that efforts should focus on improving existing projects, rather than on creating new ones, unless new projects include original approaches.

Generally speaking, documentation is a weak point. We have rejected about 9% of the projects for this reason. Even within the projects we have selected, we feel that user information should be improved. Sometimes we made the examples work with a mixture of documentation and intuition. New users should have a clear view of what software can do and where to obtain more information. However, we acknowledge that documentation is slowly improving in the projects we know for some years.

Another issue is the fact that people are not used to work with the GNU/Linux operating system and they are unwilling to change their operating system. One quick way to sort this out is by using virtualization. It is possible to use programs like *VirtualBox* [28] and *VMWare* [29] that allow users to work with different operating systems at the same time. This is a great way to try and use these free software programs that otherwise people would refuse because of the nuisance of installing and configuring GNU/Linux and the programs. It is also a great way to create an environment with the operating system and the installed programs that users can carry with them in portable media like USB memories.

In future, we plan to evaluate the selected programs in depth. For that purpose, we will use a quality model. We intend to apply a model based on the ISO/IEC 9126 standard [5] and a model specific to free software programs [7]. We want to derive from this study which is the suitability of the programs for real-world designs and where the efforts should be focused in order to improve them.

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Design of an Educational Oscilloscope

A Hands-On Learning Tool

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Abstract— **Paradoxically, most engineering students do not possess an in-depth knowledge on how an oscilloscope works. Automation is partly to be blamed for this problem. In fact, the existence of the "auto scale" button has eliminated the hassle of making adjustments, but at the price of dampening the students' curiosity and removing their need for deep understanding.**

We have found a powerful way of stimulating students' curiosity and of bestowing them with knowledge of the basic oscilloscope operation: While still using an oscilloscope-set, although merely as a display unit, we have by-passed its fundamental components (namely the vertical amplifier, the time base and the trigger circuit), with our own designed components, built outside of the oscilloscope-set. Our teaching strategy provides students with hands-on experimentation of the circuits that control vertical gain, the time scale and the trigger level. Our educational tool is *implemented in hardware*; it is not another simulation oscilloscope.

The effects of our didactic tool are highly positive, as demonstrated by student evaluation of circuit laboratories that took place before and after we incorporated the Educational Oscilloscope into the engineering curriculum. This paper provides the reader with the following educational facilities: the Educational Oscilloscope circuit schematics, as well as the explanation of its several components as provided to the engineering students at SUNY New Paltz.

Keywords-component; design; education; oscilloscope.

I. INTRODUCTION

Research has been conducted on the use of the oscilloscope as a tool for learning different topics. Examples of these topics include the engineering concepts of sampling and quantization [1], or even unsuspected topics, such as how to improve word-pronunciation by obtaining feedback from the speaker's voice signal displayed on the oscilloscope screen [2].

The focus of this paper is however on teaching the operation of the oscilloscope itself. Many books on the topic exist [3-5], but of course they provide knowledge that is theoretical rather than practical.

Several tutorials exist on the Internet where practical operation of the oscilloscope operation is taught via the use of oscilloscope simulation. In [6], the author discusses how to implement one such oscilloscope simulation with the objective of using it for on-line teaching.

Although the oscilloscope simulation approach has the advantage of showing what the different knobs and switches do, it has the disadvantage that it does not teach *why* they do it. Our educational objective is for engineering students to learn not only what the different control elements do, but mainly which circuits they control inside of the oscilloscope. We believe that students will have a better chance to achieve this objective by learning from a hardware circuit than from a simulated one. This belief created the concept of the Educational Oscilloscope.

The need for the Educational Oscilloscope was motivated by assessment of the SUNY New Paltz engineering course "EGE322 Electronics I Lab," performed by the paper's first author. As part of this assessment, there was a survey answered by the course students. One of the survey questions was: "Were you able to use the lab measuring instruments properly?" The common response of many students was that they were expected to use the instruments in the laboratory but had not received any training on how to do it. Such an obvious action had been overlooked! Using this student feedback, teaching of laboratory instrument operation was incorporated into the curriculum.

Although this action had a positive effect, student complaints about the use of the oscilloscope still remained, as evidenced by the following student's comment: "However, I still do not understand completely how to use the oscilloscope. Whenever I could not get a steady image, I would call the instructor, and he would touch the trigger control and make it work. He did not have time for explaining what he did in detail, as he was busy assisting other students."

To fix this problem, the Educational Oscilloscope was created. In order to implement the Educational Oscilloscope idea, a Senior Design Project was utilized. This Senior Design

Project was executed by this paper's second author and supervised by the first author.

II. THE EDUCATIONAL OSCILLOSCOPE

A. The Main Design Idea

The basic design idea is explained with the aid of Figure 1:

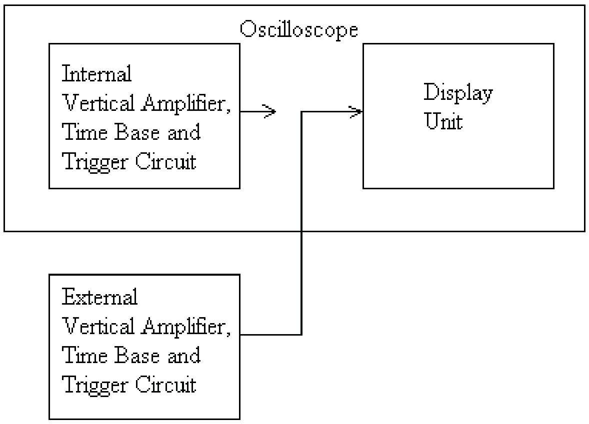

Figure1: The main idea in the Educational Oscilloscope

The oscilloscope internal components Vertical Amplifier, Time Base and Trigger Circuit are being by-passed by corresponding external components, which were designed in a Senior Design Project. The only unit retained from the oscilloscope is its display system (CRT electron beam and phosphorous screen).

With this action, the Vertical Amplifier, Time Base and Trigger Circuit have been "brought outside" of the oscilloscope unit, and therefore, students have now direct access to them. They have access to a circuit whose components they can see, touch and understand. They are able to relate operating on these components to the effects produced on the oscilloscope screen. This hand-on cause-effect interaction has a powerful didactic effect on the students' understanding of the oscilloscope operation.

It must be clarified that the external Vertical Amplifier, Time Base and Trigger Circuit are not as complex and elaborated as the corresponding components inside. As a matter of fact, for didactic reasons, our goal was to make them as simple as possible, as long as they are able to capture the essence of the internal components' functionality. As it turns out, this can be achieved by using simple Operational Amplifier, gate and flip-flop circuits, whose knowledge is acquired by SUNY New Paltz students in the Circuit Analysis and Digital Circuits courses.

B. General Block Diagram

The general block diagram is shown in Figure 2:

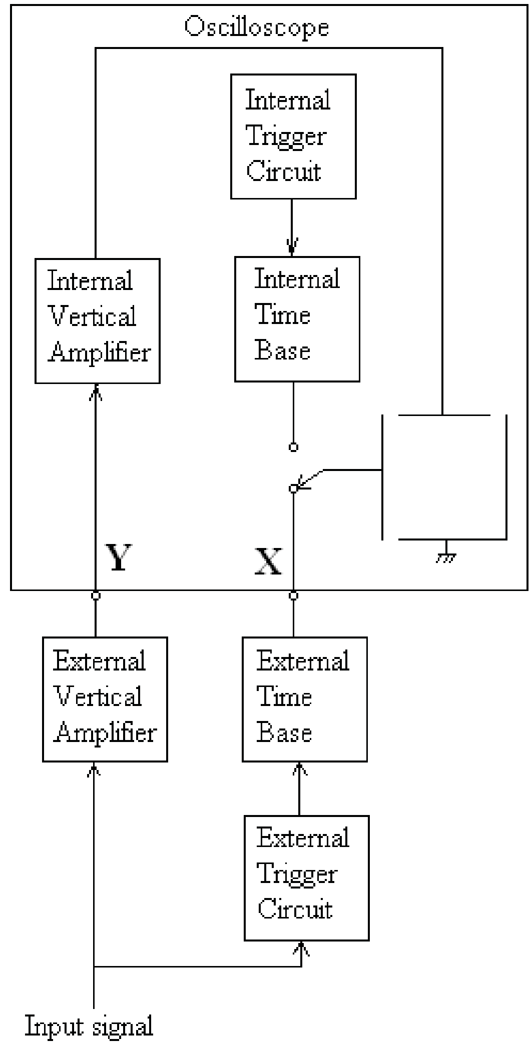

Figure 2: General block diagram of the Educational Oscilloscope

The signal to be displayed is input to the external Vertical Amplifier. This amplifier amplifies this signal with a gain that is controlled by the user. In other words, the user can control the "volts/division" by changing the amplifier's gain. The amplified signal is then output to the **Y** input of the oscilloscope. It must be noted that, although the signal experiences further amplification inside the oscilloscope, the gain of the vertical amplifier inside the oscilloscope is left fixed at a certain value, which gives the user total control of the signal amplification. (Accurately speaking, the Vertical Amplifier is the only of the three external units that does not by-pass the corresponding internal unit; it just adds to it. On the other hand, as will be seen next, the external Time Base and Trigger Circuit completely by-pass the internal ones.)

The external Time Base generates a saw-tooth waveform whose slope is controlled by the user. By changing the slope, the user controls the "Time/Division". The saw-tooth waveform is input to the "X" input of the oscilloscope and the oscilloscope is set in the **XY** mode. *This is the key idea of the design*! As illustrated in Figure 2, with this simple action, the external Time Base (controlled by the external Trigger Circuit) completely by-passes the internal Time Base (controlled by the internal Trigger Circuit). The oscilloscope's **X** input, which is normally used to produce Lissajous figures, is now used to connect the external Time Base.

By adjusting knobs on the external Trigger Circuit, the user can control the starting time of the saw-tooth waveform produced by the external Time Base. This in turn controls the instant of time at which the input signal starts being displayed. Details of the three external units are provided in the next section.

C. Individual Blocks of the Educational Oscilloscope

This section has two objectives: a) To explain to the reader the individual blocks of the Educational Oscilloscope and b) to outline the theoretical explanation on the Educational Oscilloscope that is provided to students. Accomplishing objective b) is the reason why the reader who is experienced in electrical engineering will find the following explanation simplistic. In addition, recall that the value of the paper is on education, not hardware design. The educational strategy is precisely to design very simple external circuits that are still able to capture the essential functionality of the internal ones.

External Vertical Amplifier:

The external Vertical Amplifier is shown in Figure 3:

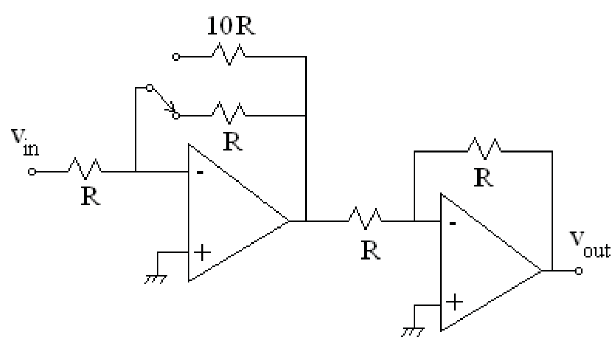

Figure 3: Schematic of external Vertical Amplifier

The equation of this circuit is:

$$v_{\text{out}}(t) = K_1 v_{\text{in}}(t), \quad (1)$$

where in the example, constant K_1 can take the values $K_1 = 1$ or $K_1 = 10$, depending on the position of the switch. The input signal to be displayed is connected to v_{in}, and v_{out} is connected to the **Y** oscilloscope terminal. Now, the vertical displacement $y(t)$ on the oscilloscope screen is proportional to the voltage applied to the **Y** terminal, that is:

$$y(t) = K_2 v_{\text{out}}(t), \quad (2)$$

where K_2 will keep the same value provided that the vertical gain control on the oscilloscope panel is not changed. Combining equations (1) and (2):

$$y(t) = K_1 K_2 v_{\text{in}}(t). \quad (3)$$

This means that the vertical displacement is proportional to the input signal through the proportionality constant $K_1 K_2$, and that thereby the "volts/division" can be adjusted externally by changing the value of K_1.

External Time Base:

The external Time Base is shown in Figure 4:

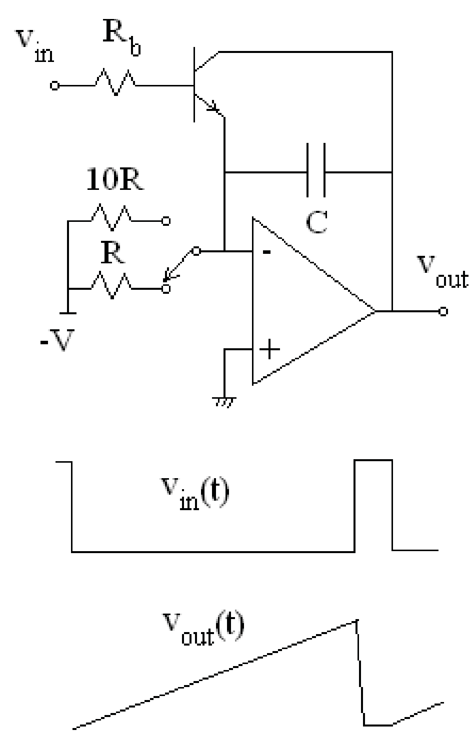

Figure 4: Schematic of external Time Base

The signal v_{in} is a digital signal. On one hand, when $v_{\text{in}} = \text{LOW}$, the transistor is off, which allows capacitor C to charge at a constant rate. This results in the output voltage being a ramp, whose equation is:

$$v_{\text{out}}(t) = K_3\, t \quad \text{for} \quad v_{\text{in}}(t) = \text{LOW}, \quad (4)$$

Where $K_3 = V/(RC)$ or $K_3 = V/(10RC)$, depending on the position of the switch. On the other hand, when the input voltage is high, the transistor saturates and shortens the capacitor, which produces:

$$v_{\text{out}}(t) = 0 \quad \text{for} \quad v_{\text{in}}(t) = \text{HIGH}. \quad (5)$$

The result is a saw-tooth waveform $v_{\text{out}}(t)$ (see Figure 4), which is connected to the **X** oscilloscope terminal. Now, the horizontal displacement $x(t)$ on the oscilloscope screen is proportional to the voltage applied to the **X** terminal, that is:

$$x(t) = K_3 K_4 t \quad (\text{for } v_{\text{in}} = \text{LOW}) \quad . \qquad (6)$$

This means that the horizontal displacement is proportional to "time" through the proportionality constant $K_3 K_4$, and that thereby the "seconds/division" can be adjusted by changing the value of K_3, which is the slope of the ramp (Equation 4). It also means that "time" starts at the instant where signal v_{in} becomes LOW and stops at the instant when signal v_{in} becomes HIGH. In order for the input signal image to be steady on the oscilloscope screen, the start and stop times have to be synchronized with the input signal. This is accomplished by the circuit described next.

The External Trigger Circuit:

The action of the external trigger circuit is explained with the help of Figure 5:

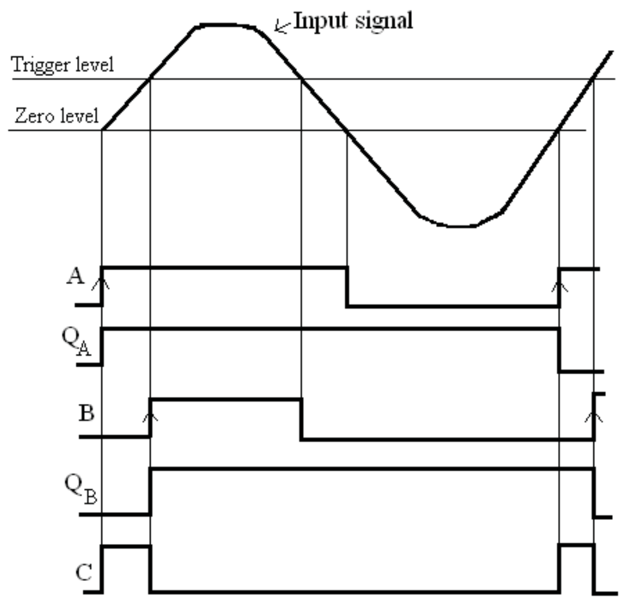

Figure 5: Waveforms in external Trigger Circuit

As illustrated by the waveforms in Figure 5, the external Trigger Circuit is very simple (remember the idea is just to capture the essence of the trigger functionality). The objective is to generate waveform C so that it can be applied to the input v_{in} of the external Time Base circuit (Figure 4). We achieve this objective in the following way: First we generate signal A, as the result of comparing the input signal with zero volts. The leading edge of signal A will be used to clock a "toggle" flip flop, thus producing signal Q_A. Then, we generate signal B, as the result of comparing the input signal to a triggering level selected by the user. The leading edge of signal B will be used to clock a "toggle" flip flop, thus producing signal Q_B. Finally, from Figure 5, note that signal C is an "exclusive or" (XOR) of signals Q_A and Q_B, that is:

$$C = Q_A \overline{Q}_B + \overline{Q}_A Q_B = Q_A \oplus Q_B \, . \qquad (7)$$

Using the precedent analysis, the circuit design of the external Trigger Circuit is straightforward, as shown in Figure 6:

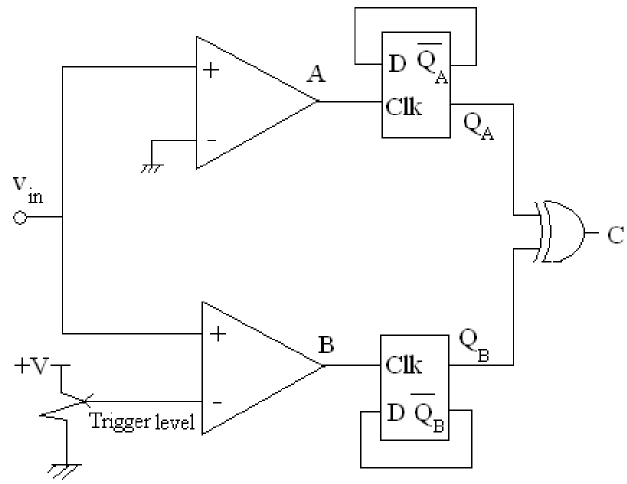

Figure 6: Schematic of external Trigger Circuit

The input signal to be displayed is connected to terminal v_{in} of Figure 6, and C is connected to terminal v_{in} of Figure 4. This means that C is the signal that controls the Time Base ramp waveform. In fact, C switching to the LOW state starts the ramp and C switching to HIGH stops the ramp. Therefore, by changing the trigger level (C switching to LOW), the user controls the start of the ramp, and thus the starting value of the displayed input signal.

In this very simplistic Trigger Circuit, the ramp is terminated when the signal crosses zero with a positive slope, and the saw-tooth waveform remains at zero value during the time interval when $C = \text{HIGH}$. Since our elementary external Trigger Circuit does not suppress the oscilloscope electron beam during this time interval, the displayed image will exhibit "retrace". Also note that this elementary trigger circuit lacks other features, such as the possibility of triggering the ramp with the negative slope of the input signal. Nevertheless, these inconveniences do not subtract from the didactic value of the circuit, which still manages to capture the essence of the trigger circuit operation.

Finally, Figure 7 is a snapshot of the input and output waveforms of the external Trigger Circuit. The sinusoid is the input waveform and the rectangular pulse is the output waveform (signal C in Figure 5).

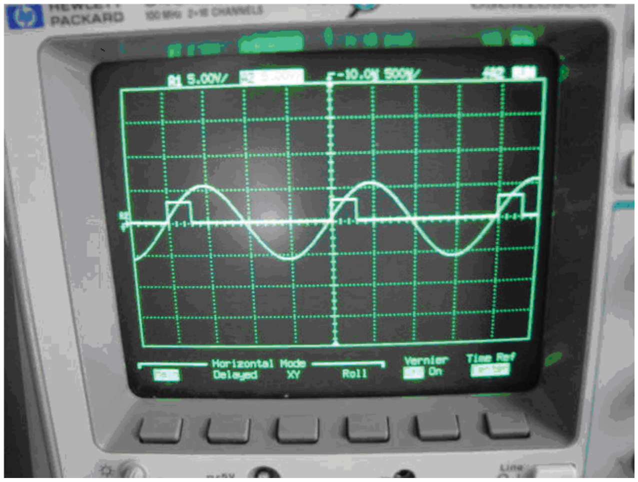

Figure 7: Waveforms of external Trigger Circuit

Figure 8 shows the previous sinusoid waveform plus the saw-tooth waveform produced by the external Time Base.

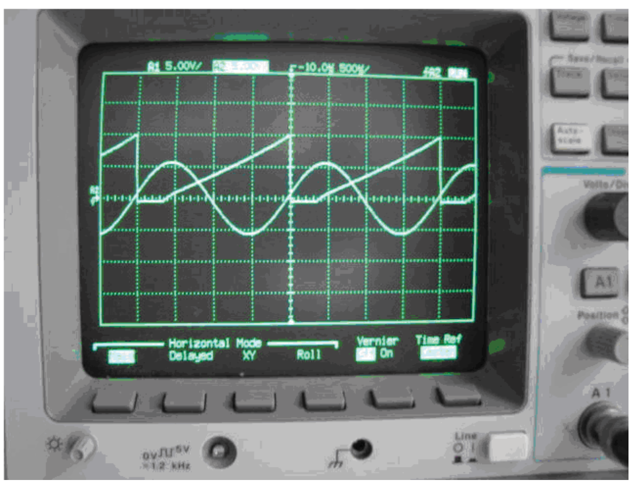

Figure 8: Saw-tooth waveforms of external Time Base

III. IMPLEMENTATION OF THE EDUCATIONAL OSCILLOSCOPE TOOL

The Educational Oscilloscope tool should not be implemented in an introductory level course such as Circuit Theory, because students have not yet acquired the theoretical knowledge needed to understand it. Therefore, students taking an introductory circuit laboratory should manage via the simplistic approach of hitting the “auto scale” button. Their time for learning the oscilloscope in more depth will come later.

At SUNY New Paltz this time is at the beginning of the course EGE322 Electronics 1 Lab. By the time that students take this lab, they already have acquired knowledge on the Operational Amplifier (as a block) and on gates and Flip Flop digital circuits, which is essential to understand the circuits used in the Educational Oscilloscope.

The Educational Oscilloscope is first introduced to the students as a lecture, which was basically outlined in Section II. After the lecture, and before students are allowed to put their hand on the Educational Oscilloscope, they are required to answer a set of questions. The objective of these questions is to force students to generate a theoretical expectation for what the consequences of their experimental actions will be. Without the students being able to produce this theoretical expectation, the didactic experience would have little value.

The questions were carefully devised to guide the learning process. There are three sets of questions: 1) Questions on the Vertical Amplifier, whose objective is for students to learn why and how the “volts/division” scale is changed; 2) Questions on the Time Base, aimed at teaching students why and how the “time/division” scale is changed; and 3) Questions on the Trigger Circuit whose objective is to teach students: a) why the time base generator has to be synchronized with the input signal and b) How to control the instant of time when the input signal starts being displayed.

Once students have answered this set of questions satisfactorily, they proceed to make measurements. By verifying their answers experimentally they gain powerful knowledge and understanding, as corroborated in the next section.

IV. ASSESSMENT OF THE EDUCATIONAL OSCILLOSCOPE

A specific assessment in the course EGE322 Electronics 1 Lab. was designed to test the efficiency of the Educational Oscilloscope tool. This assessment was conducted at the beginning of the fall 2008 semester, without the Educational Oscilloscope, and at the beginning of the fall semester of 2009, right after the Educational Oscilloscope was implemented for the first time.

The following rubrics were used in the assessment:

TABLE I: RUBRICS USED FOR ASSESSMENT

4	Deeply understands the oscilloscope operations. Consistently does all or almost all of the following: Is able to obtain the desired image on the oscilloscope screen by taking actions (operating on knobs and switches) based on his/her deep understanding. Does not need any help from the instructor.
3	Has an intuitive understanding of the oscilloscope operation. Does most or many of the following: After struggling for some time, is able to obtain the desired image on the oscilloscope screen. His/her actions (operating on knobs and switches) are based on intuition and on memorization of previous experiments. Needs minimal or no help from the instructor
2	Has a weak understanding of the oscilloscope operation. Does most or many of the following: After operating some knobs and switches, is able to get a non-stationary image on the oscilloscope screen. At this point, in order to get a steady image on the oscilloscope, he calls the instructor for help.
1	Has no understanding of the oscilloscope operation. Consistently does all or almost all of the following: After connecting wires, immediately calls the instructor for help. Usually uses the excuse: "I have connected everything like in the lab schematics, but it does not work".

Figure 9 shows the results of the assessment. The vertical bars represent the percent of students that fall in a particular rubric, as defined in Table 1. The white bars correspond to assessment performed in the fall of 2008, without the Educational Oscilloscope, and the black bars to assessment performed in the fall of 2009, with the Educational Oscilloscope.

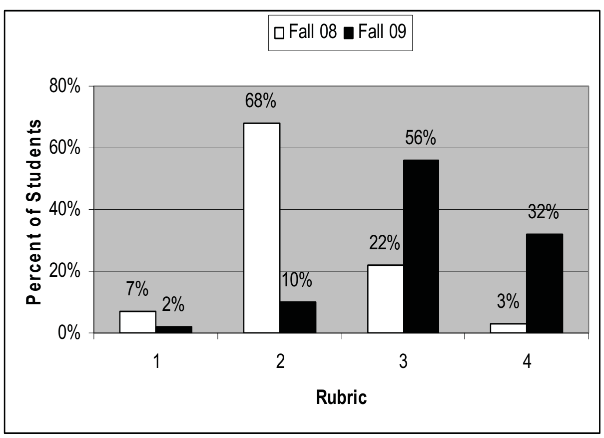

Figure 9: Assessment of Electronics 1 Lab without and with the Educational Oscilloscope

Incorporating the Educational Oscilloscope has the effect of shifting students from the lower to the higher rubrics. In fact, the student population migrates into the higher rubrics 3 and 4.

V. CONCLUSIONS

We have utilized a Senior Design Project to develop an Educational Oscilloscope, which is a powerful tool for teaching students how the oscilloscope works. The main idea is to by-pass the oscilloscope internal components by external ones that students can understand and manipulate.

The developed tool exhibits a very simple design, solely based on Operational Amplifiers, gates and Flip Flops. This is not a drawback, but rather an important didactic advantage. In fact, students who have taken basic engineering courses such as Circuit Theory and Digital Electronics are able to comprehend the design in its totality. Of course, such a simple design of the external components cannot duplicate all the functions performed by the oscilloscope internal components. This is quite acceptable because the main goal of the external components is to capture the functionality principle of the internal counterparts.

The proposed teaching approach is highly effective. This conclusion is supported by the graph of Figure 9, where we can compare the distribution of students in the different rubrics for the cases a) without the Educational Oscilloscope (white) and b) with the Educational Oscilloscope (black). We can see that the student population mainly migrates from the lower rubric 2 to the higher rubrics 3 and 4. According to the definition of rubrics in Table 1, this means that an increased number of students become better at completely understanding the oscilloscope operation, or at least they are able to understand it well enough that they do not need assistance from the instructor.

ACKNOWLEDGMENT

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Session 11D Area 1: Computer and Web based Software - Security and Data Bases

Database Teaching tools

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Management and Optimal Distribution of Large Student Numbers

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Enhancing Database Querying Skills by Choosing a More Appropriate Interface

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State-of-the-art simulation systems for information security education, training and awareness

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DataBase Teaching tools

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***Abstract*— This paper is about how to improve the experience of students of the subject of database theory and practice, a subject many find somewhat daunting. It is by experiment that most scientists learn most about their discipline and in this paper the following ideas can be explored in simulations that in most cases use access to a database so that the exercises are personalised.**

The simulations are listed below.

- **Simple Entity-Relationship diagrams: Where simple Entity-Relationship diagrams can be composed from a set of components and their validity checked.**
- **Entity-Relationships and tables that describe the entities: Where the student has to decide from tables of two entities the degree of participation and the participation conditions. With prompting the correct solution can be found and as many attempts as necessary are possible.**
- **Structured Query Language (SQL): Given a database various SQL queries can input and the way that the queries are dealt with are shown in detail not just the final result.**
- **Functional dependency: Given a table from a database this can used to find out whether there is any functional dependency between any of the columns and also to show what the primary key/s might be.**
- **Normalisation: A topic that confuses may students. This allows table to be split into a number of sub-tables and the result can be tested as to whether the selected table can be joined together to form the original table.**

Each of these ideas has a simulation and these will be discussed in terms of how to run the simulation and explaining what the simulation is trying to teach. There are some third party software requirements and these will be explained together with the solution that is used for the demonstrations.

Keywords-Entity Relationship diagrams, participation conditions, multiplicity, Structured Query language, Tables, Normalisation, Functional dependency

I. INTRODUCTION

The tools are designed to be used with any database as they have a configuration files that are used to specify the ODBC-JDBC connection. There are also data files that can be used to store queries that have been used and have been shown to produce correct results. These data files are necessarily different for the various applications. For demonstration purposes a number of small databases files have been constructed that are typical database applications, one concerns a mythical Hospital and another, an online University.

To allow for connection a number of databases a configuration file is used that contains the details of the connection request required by the databases. The purpose of introducing a number of databases is to show that the software, written in java, is generic and can thus be customised by the user without any need to change the software. The configuration file format for the Open University course [7] which uses SyBase is shown below:

```
Hospital;jdbc:odbc:HospitalDSN;m359;m359
University;jdbc:odbc:UniversityDSN;m359;m359
```

Similar formats are used for the corresponding Excel and Access files.

```
University_Excel;jdbc:odbc:university;"";""
Hospital_Excel;jdbc:odbc:hospital;"";""

Hospital_Access;jdbc:Access:///C:/Netbeans_M359/Hospital.mdb;"";""
Univesity_Access;jdbc:Access:///C:/Netbeans_M359/University.mdb;"";""
```

The separator used in the Java simulation program is ";", the semi-colon and hence its use in constructing the entries in the configuration file

II. BACKGROUND

The idea of an Entity-Relationship model dates from 1976 at which time the paper by Peter Chen [1] proposed unifying the models that had been used prior to that, the network model, the relational model and entity set model to that of the Entity-Relationship model. Appendix 1 shows instances of each of these derived from Chen's paper. The idea of mandatory and optional participation does not appear to be supported at this time.

It seems that it took academia another six years before there was any publicised interest in applying these ideas to the teaching of database technology. Carol Chrisman [2] introduced the idea of using entity relationship models as a tool in the teaching of database design using the entity relationship approach. The notation used is that of Chen.

Then in 1987 another author Judith D. Wilson [3] takes up the baton and analyses some of the problems associated with how students use entity-relationship model and how to circumvent them.

An interesting contribution as regards using computers to help in learning SQL came in 2004 from tutors at the University of Queensland, Australia [4]. It was called SQLator and enabled students to check the correctness of a query before submitting it to a database. It was however limited to this one application and did not concern itself with entity relationships.

In 2007 Edward Sciore [5] introduced a system that dealt again with SQL but this was concerned with how an SQL query was processed in the computer that hosted the application.

In 2008 there was another SQL query simulation [6] that dealt with a range of queries that would be used in the construction and testing of a database design, but again notice limited to this one area. This paper was as much interested in how the system dealt with the query as to how structure the query

III. ENTITY-RELATIONSHIP DIAGRAMS

A. The Graphical User Interface (GUI)

This is the only tool that is based entirely on simulation. At this stage of learning in a database course it is only concepts that need to be learnt. The tool can be personalised using component names that are part of the course and also Chen's notation or Crows foot notation can be used As can be seen from Figure 1, the screen shot of the simulation, there are four text areas and a number of graphical symbols. The two entities are shown together with the relationship that exists between them. The purpose of the exercise is place two of the participation conditions at either end of the relationship and for information about the choice to be displayed in the text areas.

In some cases the choice is a combination where a simple relationship is not possible but has to be represented by a Relation for Relationship instead. The screen is slightly redrawn with another entity in the centre and relationships connecting all three entities. An explanation to this effect is given in the top text area, it is hoped that this is sufficiently detailed for the student to continue with what can be a difficult choice.

B. Information files

There are two sets of files relating to the text areas they have been called Explanations and Relations. For some users the explanations may need to be expanded and this is obviously possible as they are only text files. There are however some twelve files that would have to be changed for it to be complete

a. Explanations

These describe how the two entities are related in terms of participation conditions that have been chosen they appear in the top text area. An example where a RELATION FOR RELATIONSHIP has needed to be used

"Entities A and B have discretionary participation as is shown. But now the 'many' relationship of entity B to entity A is replaced by the 'many' relationship of the entity RELATIONSHIP with entity A. Both participation conditions for the entity RELATIONSHIP are of necessity mandatory"

b. Relations

These set out the entity descriptions in a table format as would be used when starting the potential design of a new database. The student then gets used to this type of presentation.

"Relation RELATIONSHIP
A1: A1s
B1: B1s
primary key A1, B1
foreign key B1 references A.
foreign key A1 references B."

An example of the text in the lower middle text area that is included when a RELATION FOR Relationship has needed to be used.

Foreign and primary keys are shown, as would be the case, in the other two lower text areas.

C. The exercise

The student is presented with the initial screen and has some instructions that explain the meaning of participation conditions and multiplicity and is encouraged to see how the entity table for each entity is set out in the text areas above each of the entities. Any combination of symbols is possible and the result for each should be noted. When those choices that give rise for the need of a Relation for Relationship are chosen, the student would be encouraged to note what these were but not pursue it but continue without completing that choice until all choices had been tested.

The pairs of symbols that do not require a Relation for Relationship are now known and these can be used to try and satisfy the situation where symbols have to be attached to all the three entities that are shown. The first text area gives some clue as to what might be an appropriate choice.

Figure 2 shows a completed exercise where the initial selection of participation conditions was optional and both ends had single occurrences. An explanation of why this representation is required is given in Appendix 2

D. The lessons learnt

The student should have now some understanding of how relations are expressed in the definition tables. How the domains are shown and how the primary and secondary keys are shown. There should also be some understanding of what is meant by a foreign key and hopefully why they are needed.

The relation for relationship idea will need further explanation but at least the idea will have been firmly entrenched.

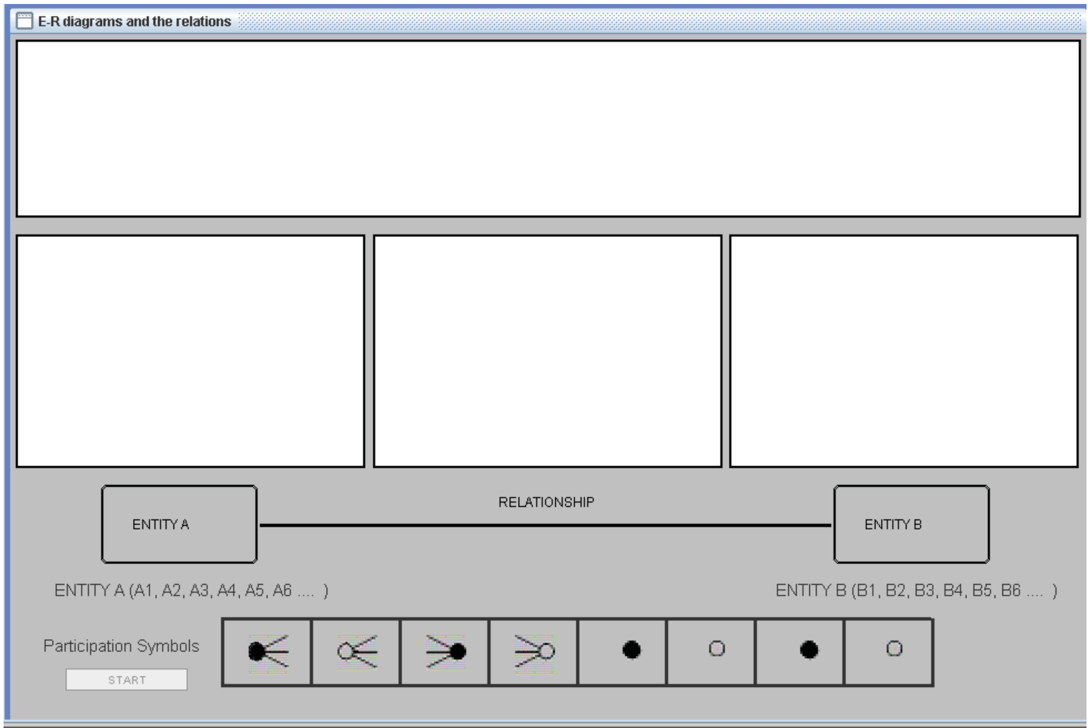

Figure 1. The initial screen for Entity Relationship diagrams.

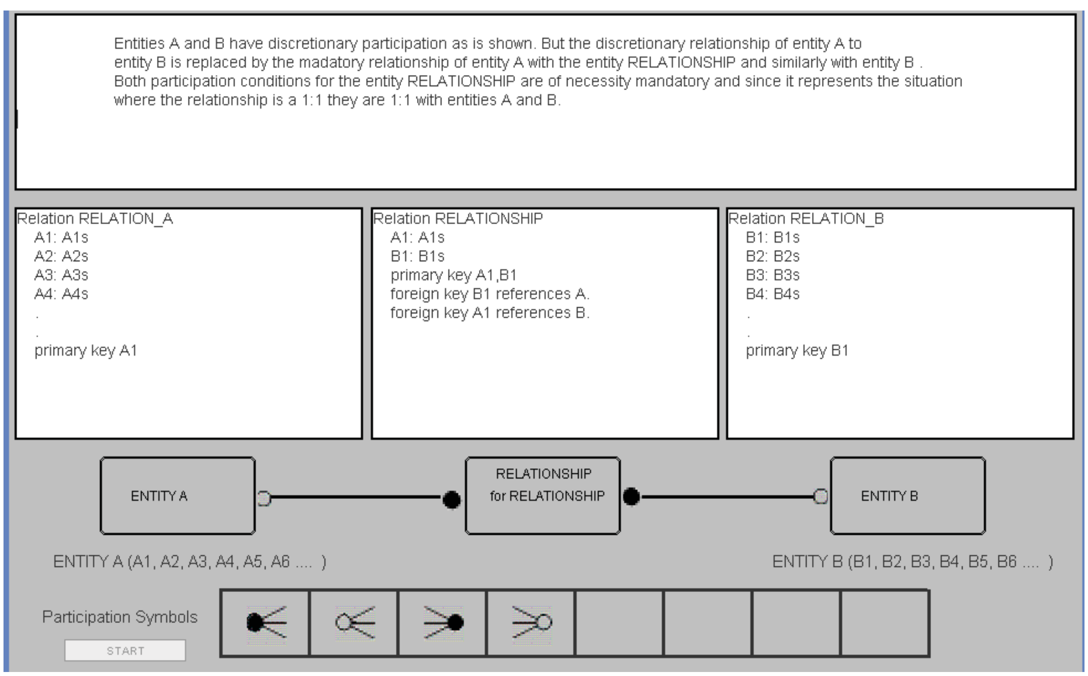

Figure 2Tables and ER diagrams that correspond to them

IV. ENTITY-RELATIONSHIPS AND TABLES

A. *The graphical user interface (GUI).*

There are three drop down menus, one to choose the database and two that choose individual tables from that database. The tables are displayed in their entirety once they have both been chosen. Two panes display the tables selected and the progress of the exercise.

For this tool it was decided to use a database for the data that was needed as this the simplest way of ensuring that the tool was general purpose and could be used on any database

Figure 3 shows the screen after a student has completed an exercise successfully. The same drawing and symbols are used as for the entity-relationship diagrams.

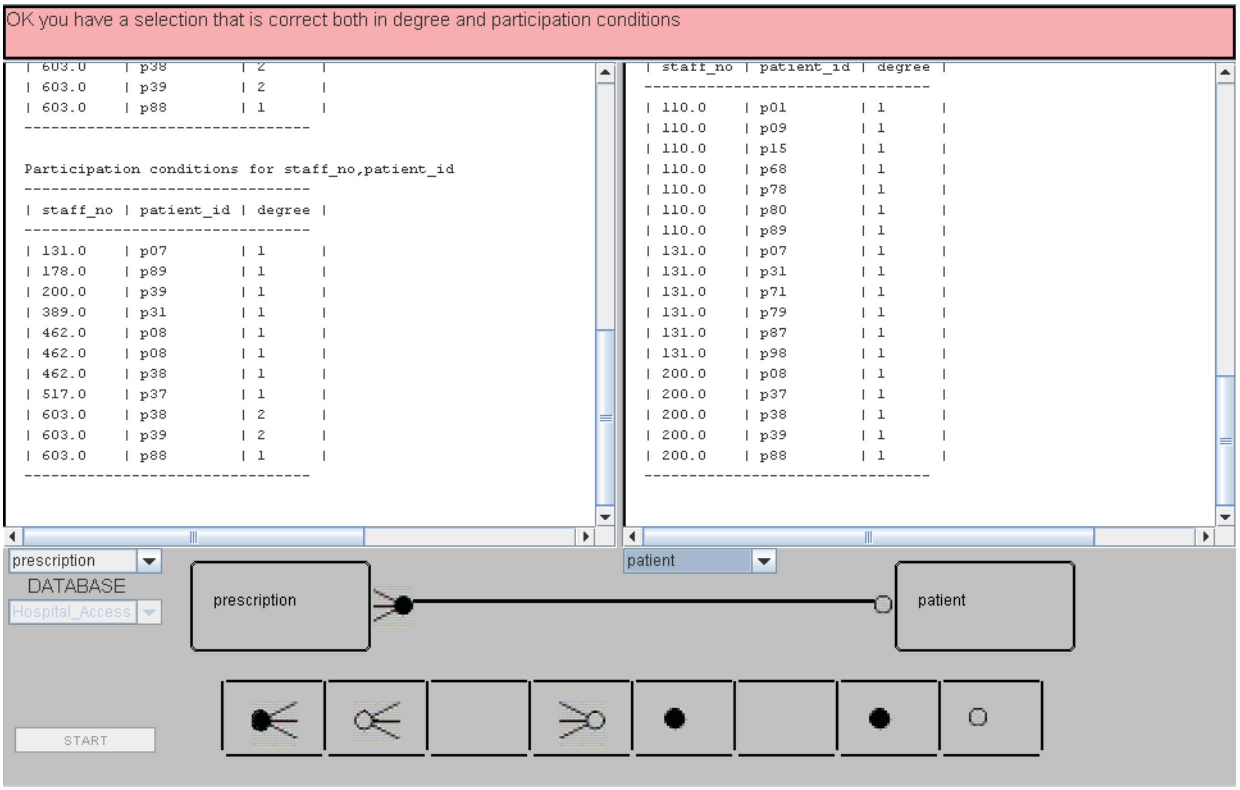

Figure 3Tables and ER diagrams that correspond to them

B. *The exercise*

Initially no database is selected and no tables. The top drop down menu on the left-hand side has a choice of database.

Some of the databases that are used relate to an Excel files some to Access files and some to Sybase files although in fact they contain the same data. When the database has been selected the other two drop down menus are available and tables form the chosen data base are listed. A choice has to be made for each menu and the table for each is displayed.

The student has to study the table and decide upon the participation conditions in degree and whether it is discretionary or mandatory. The symbols are chosen to reflect their decisions and placed on the ER-diagram. Whether this has been success or otherwise is shown in the upper text area with messages such as:

"OK you have a selection that is correct in degree but not participation conditions change the conditions" OR perhaps

"Wrong symbols chosen use the database output to make a better informed choice of symbols".

The progress of the exercise is thus apparent and only complete when the student gets the message *"OK you have a selection that is correct both in degree and participation conditions"*.

The first message means that the multiplicity of one or both the symbols needs correcting but that the participation conditions whether they should be shown as mandatory or discretionary has been achieved. The second message indicates that neither of the choices made is appropriate. In either case the table content is condensed so that for each entry in each table the degree of participation is shown and this makes the choices more apparent.

Notice that after the tables have been selected and the student has made an initial choice of symbols that screen is updated to show the participation conditions in degree for the common key between the two tables. This is helpful especially in the situation where the tables a long.

C. The lessons learnt

The strongest lesson here is the fact that trying to appreciate a mass of data can be a daunting exercise, even for the relatively small tables that are available, and that reducing the size of the problem by looking only at the primary key and the multiplicity of the key it is then possible to analyse the data visually more easily. Also it should be possible for the ideas mandatory and discretionary participation conditions to become clearer.

V. STRUCTERED QUERY LANGUAGE (SQL)

A. The graphical user Interface (GUI)

There are two text areas, one to show the output from the database for a query that has been input and a second one used to write a query. This text area is editable but can also have text inserted from a multiple choice drop text box. The database source can be chosen from the databases that are available and which have been written into the configuration file.

There is also an area on the screen where the meta-data corresponding to the chosen database can be displayed if the metadata exists, these are the table names and the column names within the database. This is useful when framing a query as these details are needed to write a correct query.

B. Query examples.

And typical entries for the University database, for SQL queries, are also as below:

SELECT * ; FROM staff;
SELECT name, staff_number ; FROM staff;
SELECT DISTINCT staff_number ; FROM tutors;
SELECT staff_number ; FROM staff ; WHERE name = 'Jennings';

C. The scope and format of the simulation of SQL queries.

The simulator is capable of dealing with queries that contain:

- SELECT clauses
- FROM clauses
- WHERE clauses
- GROUP BY clauses
- HAVING clauses and
- ORDER BY clauses
- And a single level of nesting

The simulator not only carries out the processing of the requested query but shows all of the steps in the logical processing model in the order that the database would carry out the necessary calculations. The tables are shown separately and titled to show their relevance to the various stages.

B. The exercise

Figure 4 shows the result of displaying the result of the query “SELECT AVG (height) AS average_height FROM patient”. The screen shows the complete SELECT clause and just the heading for the FROM clause. The order in which they are displayed is the order in which the database will process such a query.

The exercise proceeds by the student choosing the database from the upper drop down menu and then if a table of queries exists the query that they wish to run. Alternatively if the query that the student wishes to run is not available this can be typed into the upper right text area. Of course they have to get the syntax right for query to give any result.

The Sybase examples have metadata associated with them that allows the display of the columns of the relations. This is more of an aid to memory but it can be useful to have that information on the screen rather in a book that has to be searched through.

C. The lessons learnt

There are many lessons that the student will learn from experimenting with prepared queries and queries that they structure themselves.

The way that the various stages of the query are shown will help understand how the database deals with a query and also to construct their queries in a way that the database will understand.

They will also learn the need to be absolutely correct with the syntax of their own queries because otherwise the database will give an error message which usually is not that informative.

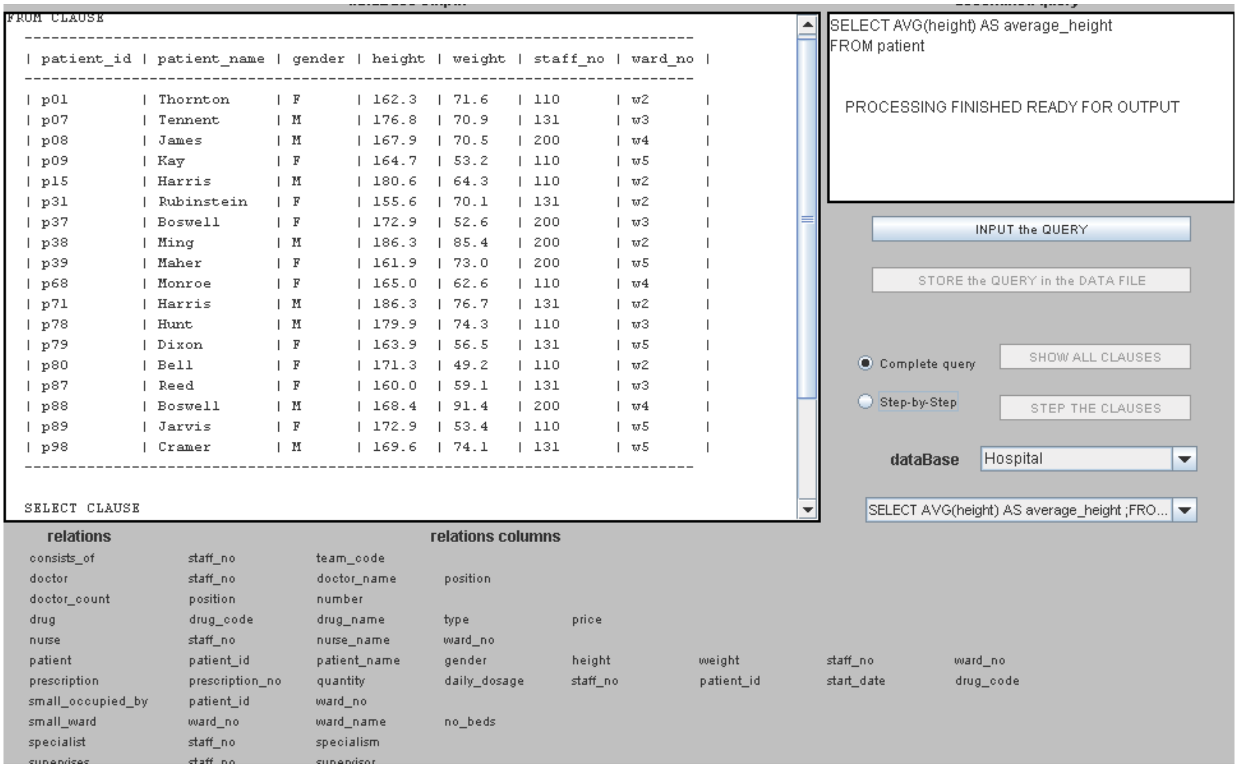

Figure 4 The screen showing the "FROM and SELECT" output

VI. FUNCTIONAL DEPENDENCY

A. The graphical user Interface (GUI)

As can be seen, from Figure 5, there are three areas shown on the right hand side of the screen, they have scroll bars that appear if necessary. The three areas are to display the results of single, double or triple determinant terms used for finding any functional dependencies within a table. There is screen area where the table is written out and three drop down menus and two buttons. The dropdown menus are used to choose a database and a table from that database or a data source being an individual page.

The far left hand button allows the exercise to be restarted at any time but preferably when one exercise has been completed. The reset selection button is used to begin a search through the table once a determinant has been chosen. The determinant is set via the check boxes above each column.

B. The exercise

As explained in the GUI description the START/RESTART button is pressed and that allows the choice of the database followed by the choice of the table.

The determinant to be tested is then chosen and the when satisfied the START SEARCH button is pressed. The student now has to work a little bit harder. The table has to be stepped through for each of the columns that are not part of the determinant. Once a column has been stepped through and a dependency is detected between the chosen determinant and the column then this is notified in one of the text areas at the bottom depending upon the length of determinant that has been selected.

This same procedure has to be carried out for all of the columns not within the determinant chosen. Clearly if all of the columns give rise to a notification of a dependency then a possible primary key has been found.

Various combinations can be tested but they should be combinations that the student thinks from observation would have some dependencies between the chosen determinant and the remaining set of columns.

C. The lessons learnt

A student with little idea of the meaning of functional dependency would eventually grasp the idea that it meant that for each particular determinant there could only be one instance of a parameter with a particular value in a column if that column was functionally dependent. If the column had two entries of the same value that there would be no functional dependency for that column. They would be able to understand the meaning of a primary and perhaps secondary key if there were one in the table The significance of the results should be seen when using the normalisation simulation as normalisation depends upon being able to identify any dependencies within the table

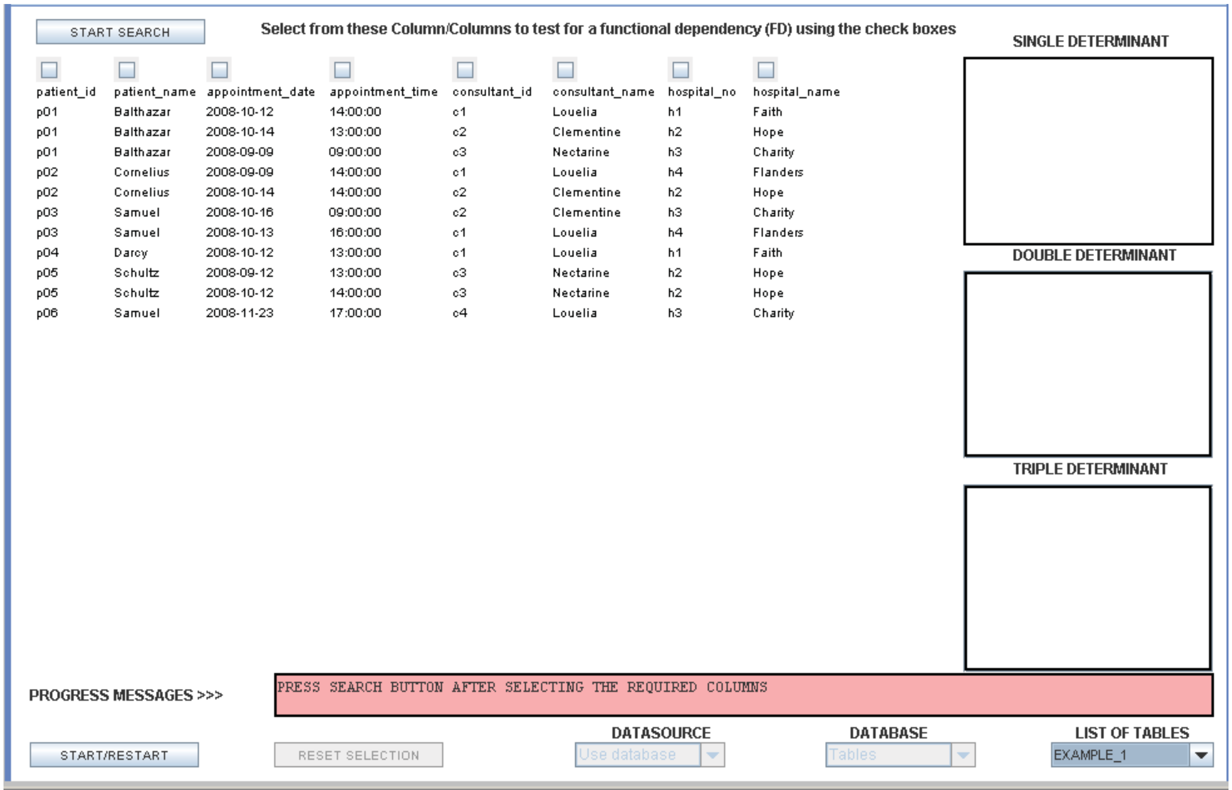

Figure5. The initial screen for functional dependency exercises where the database and table have been chosen

VII. NORMALISATION

A. The graphical user interface (GUI)

Figure 6 is a condensed view of this interface being in fact three pages to allow the display of the relatively large amounts of data that is possible using this particular tool. In Figure 6 the interface is shown part the way through an exercise. There are two prominent text areas; the top one is where the selected table is displayed and the lower one where de-selections of columns from this table are shown separately. The top text area also has a number of check boxes to allow the columns chosen in a selection to be indicated. There are drop down menus used to choose a database and a table within that database.

Initially the SHOW SELECTION button is enabled and when pressed will display the columns chose in the lower area. In order to make a fresh selection the RESET SELECTION button has to be pressed which resets the check boxes.

When the student is satisfied with all of their selections the RECOMBINE button is pressed and this joins the separate tables into one table. If the selection has been carried out correctly the original table will be drawn in the lower text area. If there has been a mistake and there is no dependency between the tables the table that results are dependant on which database is being used. For the Access databases the table that results is much longer and clearly wrong in this context. For the Sybase files the database indicates an error because the selections cannot be joined. The Excel databases cannot deal with joins and thus always give an error even if the table has been correctly partitioned.

B. The Exercise

This exercise should really be carried out after examining the chosen table for dependencies and the student should use the results to make an informed choice of selections. Selections are made and the recombination that results studied and explained even if there are errors. An example of a very small table is given in appendix 3 and it shows the effect of correct and incorrect normalisation.

C. Lessons learnt

Students find normalisation quite confusing and being able to experiment with different selections can help in lessoning the confusion. They learn how to split tables into a number of tables where the columns are sensibly grouped to include information that is relevant to individual tables. They learn to discriminate between what is needed in a table and what can usefully be put into a different table. They also learn that to be able to recreate the original table after division that there has to be information in both tables that is common to both tables and has some dependency. They should also appreciate the benefit that using the functional dependency simulation has given to them in running this simulation.

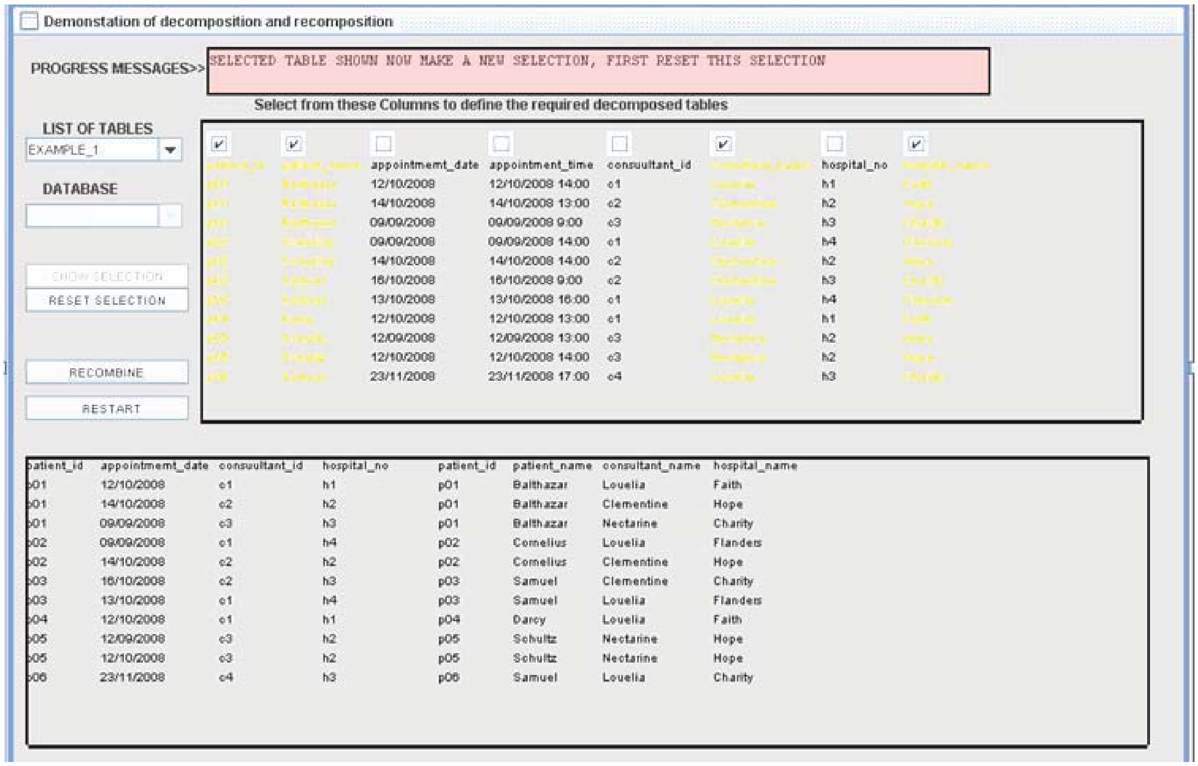

Figure 6. Selection of Tables prior to recombining them

VIII Third party software

To demonstrate that the simulations that involve access to a database a number of databases that are readily available, if not freely available have been used. MicroSoft Excel and MicroSoft Access are generally available to students as MicroSoft now offers fairly generous discounts to students so these were obvious choices. The Open University course ‘Relational databases: theory and practice’ uses SyBase for much of the SQL that the course uses and hence its use here.

Each of the databases used must have an ODBC data source registered with the Administrative tools of the host computer, such a registration is similar to the one in Figure 7. Figure 8 shows the need to specify the path to the database file in the case of an Excel file.

Excel has an ODBC-JDBC bridge as part of Excel so this would seem a great convenience to use Excel. It has its drawbacks as Excel lacks some of the facilities of a full database. Access does not have a bridge included and this did seem to be stumbling block at one point. However, a solution was found that had all of the capabilities required an ODBC-JDBC bridge from Hongxin Technology & Trade Ltd.

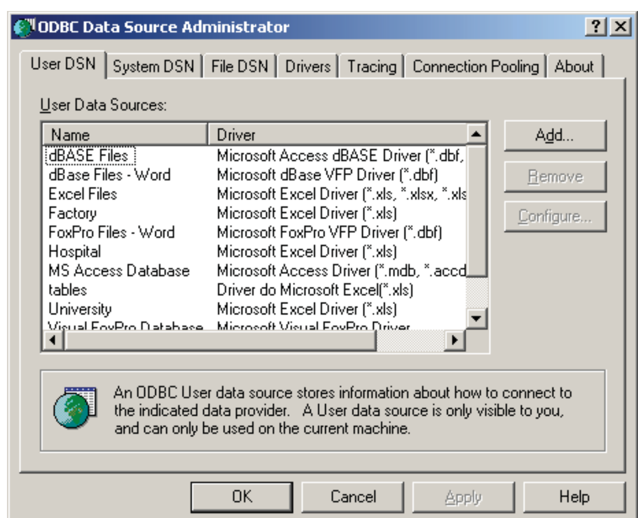

Figure 7 The user DSN examples.

The specification states “*HXTT Access packages include a Type 4 JDBC driver. Type 4 indicates that the driver is written in Pure Java, and communicates in the database system's own network protocol. It supports { UNION | INTERSECT | EXCEPT | MINUS } [ALL] query , INNER JOIN, FULL JOIN, LEFT JOIN, RIGHT JOIN, NATURAL JOIN, CROSS JOIN, and sub-query which includes single-row sub-query, multi-row sub-query, multiple-column sub-query, inline views, and correlated sub-query.”*

Sybase is a full database but does require a more complex setting procedure.

For students it might be a useful exercise for them to set up some Excel and Access files them selves. Full instructions can be found online from JavaWorld.

VIII ACKOWLEDGEMENT

I wish to thank Tony Valsamidis a senior lecturer at the University of Greenwich for his help in making it possible for some of these simulations to be tried out in the classroom in 2010.

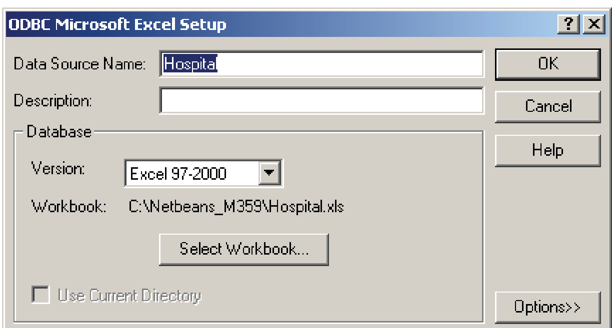

Figure 8 File setup as used

IX TESTING

Testing of the tools is to be carried out in 2010 and some results may be available later in 2010. The consensus of those that have seen the software is that it should help in students' understanding of relational database principles

X REFERENCES

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[7] Teaching material used for the Open University course M359 “Relational databases: theory and practise” first published 2006

[A summary of the M359 Open University course material is availbale on 'OpenLearn]

XI Appendices

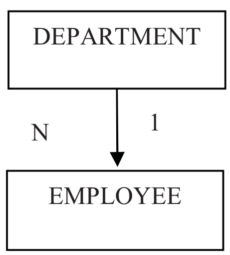
Appendix 1

A relational model of employee

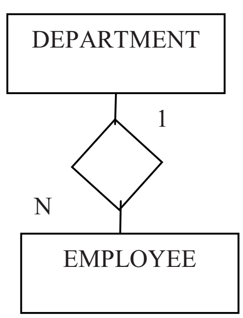
Role		Legal	Legal	Alternative	Alternative	
Domain	Employee-number	First-name	Last-Name	First-Name	Last-Name	No-Of-Years
Tuple	2566	Peter	Jones	Sam	Jones	25
	3378	Mary	Chen	Barb	Chen	23

Employee is the Relation and the components of the domain are the attributes.

A simple Network model



The equivalent entity-relationship diagram

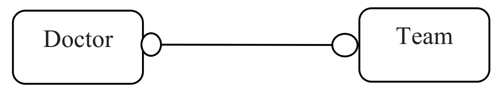


The above are all taken from Chen's paper.

Appendix 2

An example where the Relation for Relationship is needed

Consider a relationship had optional participation at both ends and use the example shown in figure 9.



Doctor (StaffNo, DoctorName, Position)
Team (TeamCode, TelephoneNumber)

Figure 9 an inadmissible Entity Relationship

Some teams are not headed by a doctor and some doctors do not head teams. That is none of the alternatives for the placement of the foreign key would not be possible, since the key indicates mandatory participation on the part of the owner of the key. Some doctors would not be associated with a team and some teams would not be associated with a doctor. In cases such as this, we have to introduce a new relation to represent the relationship.

Appendix 3

Sample table 'quota'

course_code	limit	date_reviewed
c2	3000	2007-10-01
c4	250	2007-10-01
c5	250	2008-04-23

The determinant course_code has a dependency between limit and between date-reviewed. Thus splitting the table into the two tables (course_code, limit) and (course_code, date_reviewed) would, when recombined give the initial table, but For the determinant 'limit' splitting the table into two tables of (limit, course_code) and (limit, date_reviewed) would produce the table

c2	3000	2007-10-01
c4	250	2007-10-01
c4	250	2008-04-23
c4	250	2007-10-01
c5	250	2007-10-01

Two rows that were not present in the original table have been introduced.

Management and Optimal Distribution of Large Student Numbers

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Abstract— **In principle, timetabling problems appear at every school and university. However, the degree of difficulty increases dramatically with an increasing number of students and courses for which the scheduling shall be carried out. From the mathematical point of view this is a "hard" problem, since the runtime on a computer cannot be estimated by a simple law (i.e. by a polynomial law) by the number of parameters. These kinds of problems are called "NP hard". There are three important versions of the timetabling problem at universities, known as the university timetabling problem, i.e. curriculum-based course timetabling, post-enrollment timetabling and examination timetabling.**

All specified problems are important for room management at universities, for the realization of courses that can be studied according to curricula, and for the satisfaction of students and teachers. These problems are related to the optimization of room management and personnel costs (e.g. by a uniform distribution of students). Thus, the solution to these problems is related to the optimization of "real" costs, a more and more important economic factor at (German) universities. Introduction of the two-tiered Bachelor and Master courses has raised awareness for these problems at German universities: due to the multitude of new courses the timetables which have been established and stood the test of time cannot be used any longer. Moreover classes tend to be more structured and have strong similarities to classical school situations; attendance is compulsory and dependencies between modules determine the feasibility of the curricula. This feasibility is also evaluated while accrediting new study courses. Since 2003, we have been using using an algorithm that has been realized by members of our team for the solution of the post-enrollment-based course timetabling problem at the Technische Universität Berlin. .

For classes with more than 2000 enrolled students, organization by itself is a challenge; problems may include splitting of those classes into several separate lectures, arranging the associated tutorials into small groups of students, allocating adequate rooms, and scheduling examinations. Moreover, homework and exams need to be administered, whereby, depending on the field of study, very different rules are to be obeyed. This especially pertains to the Department of Mathematics because it offers most of the compulsory classes in mathematics for all fields of study held at Technische Universität Berlin. These are the biggest classes at the university and are to be attended by the majority of students. Thus, the Moses (Mobile Services for Students)-Account has been being developed and used since 2004. This web-based software allows students to enroll in tutorials with a list of preferences for given dates. A special algorithm, providing a globally optimized (with respect to the students' wishes and resources available) solution, processes all registrations.

Keywords—university timetabling, academic administration, integer programming, NP-completeness

I. INTRODUCTION

One of the major challenges facing universities is the organization of the study supporting processes, especially for first year students. With about 28.000 students, TU Berlin is one of the German universities of technology with the largest student body. As a service for other schools, the Department of Mathematics is in charge of the mathematical education of most students, irrespective of their actual course of studies, making it the biggest „service provider" of the university. Since a major reorganization of the math-service seven years ago, every year, several thousand students from 18 different courses of studies are participating in one of the six „math-service" engineering modules (Analysis I-III, Differential Equations, Integral Transformations & Partial Differential Equations, Linear Algebra), altogether filling 9.000 to 10.000 spots in the above-mentioned modules. The largest class is the freshman course in Linear Algebra with a total count of more than 2.200 students per semester. The modules are organized as follows: In order to guarantee lecture class sizes of less than 350 attendees, one and the same lecture is being held numerous times throughout the week, sometimes even at the same time. The lecturers of the individual classes take care of presenting the same mathematical material to all attendees. In addition to lecture classes, all students have to solve the same exercises as homework and, in the case of passing the homework assignments are admitted to take the written examination at the end of the semester. Students also are eligible to attend small-sized recitation/exercise classes (so-called tutorials) in which the material of the lectures is manifested. The following list summarizes the administrational duties for performing these classes:

- Assigning all students to exercise classes
- Managing homework scores for admission to final examinations and course credits
- Managing registration of students for examinations
- Informing students about examination scores
- Collecting and submitting examination scores to the university's central examination office

Although all of the above tasks are typical administrational duties for student management at universities, the large course sizes make them very time-consuming and labor-intensive. This is especially true for the assignment into exercise groups for every module: All students have to be assigned to small (meaning total sizes of 15 to 30 students each) groups/tutorials in a way that assignments neither conflict with each other nor conflict with the individual schedules of the students while respecting certain capacity restrictions. However, the large course sizes not only present difficulties; they also imply a great opportunity of rationalization in the student administration. Against this background the development of MosesKonto (acronym for Mobile Services for Students and Konto as the German word for account) began in 2002 and was initially deployed in 2003 and has been used ever since — first for all math-service classes described above. Since the fall semester 2005/6, the assignment into exercise classes and management of exams has been extended to cover further courses, even across different schools. In 2002 we started with 5 math-services classes, in the fall semester 2009/10 54 classes offered by six of seven schools of TU Berlin are using the MosesKonto to create conflict-free timetables for their students.

II. TIMETABLING

Timetabling problems have always been an important administrative issue at universities. Due to the Bologna process [1] the construction of timetables has become more and more complicated, mainly caused by the diversity of the newly created courses of study. Consequently the need for IT-aided systems has grown. Unsurprisingly a huge amount of literature has been published over the last years ([2], [3], [4], [5], [6]). The university timetabling problems have been grouped into three parts: the university course timetabling [7], the post-enrollment timetabling [8] and the examination timetabling problem [9] . Focusing on these three problems within the scope of the PATAT 2008 [10], [11], [12], [13], an international timetabling competition (ITC2007 [14]) for solving standardized problem formulation was carried out.

A. Problem definition

The problem we focus on is related to the post-enrollment timetabling problem, which occurs for big lectures (typically with several hundreds of students) for which several small exercise/recitation classes are offered. These so-called tutorials are offered at different times and the students have to be distributed into these tutorials taking into account their individual constraints, e.g. students are enrolled in different lectures with accompanying tutorials. This means that many students with individual time constraints have to be matched conflict-free to one or more tutorials with different time slots. In general these constraints are known as "hard constraints", i.e., a timetable violating some of them is not suitable. A timetable satisfying all the hard constraints is called a feasible timetable. Furthermore the students are able to give a rating for the time slots (often called "wishes" or "soft constraints"). The goal of our solution approach is to find a feasible timetable which meets the student ratings as closely as possible. For us this seems to be an appropriate procedure for the post-enrollment course timetabling problem at a huge German university. Comparing our formulation to the one of ITC2007 we have to note that the hard constraints are both identical, but in the soft constraint definition the formulations differ a lot. In our opinion, solving our problem formulation (using our soft constraints) is easier than optimizing the problem formulation of the ITC2007. However, when comparing the problem sizes, we see that our problem with more than 5.000 participating students, more than 700 events and more than 17.000 tutorial-seats is much bigger than the problems of ITC2007 [15].

At the beginning of the project in 2002, we looked for a commercial software tackling our specific timetabling problem. To the best of our knowledge no suitable software tool satisfying our requirements was available at that time. By now several providers of timetabling specific software solutions exist, commercial ones as Scientia [16], CELCAT [17], Mimosa [18] or EMS [19], and non-commercial ones, as UniTime [20]. However, we believe that none of them can either cope with such huge problem instances like ours or do they have the same problem definition.

B. Solution method and comparison

The optimization step involves the computation of all assignments of students into tutorials, in a way that room and teaching staff capacities are respected and the computed solution is optimal in respect to the chosen priorities of dates. The problem admits a formulation as a constrained minimum-cost-flow network problem (Fig. 1, for details see [21]).

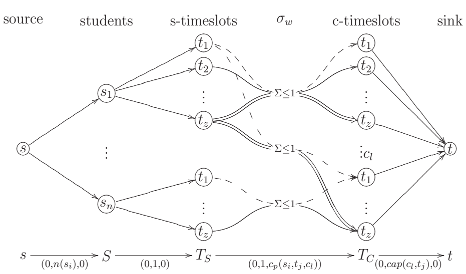

Figure 1. Network for several courses (boundaries and costs for all edges are denoted symbolically in the lower row)

To describe this in terms of a network flow problem let s Є S be a student. Nodes t_j Є T_S , representing distinct time slots, are linked to the student and each link of such a node to another t_j Є T_C represents a rating. Each t_j Є T_C represents one or more tutorial of the course C at this time slot, and *cap*(t_j,c_l) defines the capacity of this tutorial for this time slot as the upper bound of the arc linking the tutorials with the sink. The total demand for tutorials is defined as the flow at the source s. To safeguard that each student is assigned exactly to one seat in a tutorial for each course, some bundle cuts w are defined, forcing this property.

The resulting integer linear program finds a solution in acceptable time, i.e. within less than one minute for the largest instances seen so far on a recent machine. The data of the MosesKonto are accessed and preprocessed by the software TUTOP [22], which also formulates the integer program that is then to be solved by the commercial software CPLEX [23].

$$\min \sum_{s,c,ts} prio(s,ts) \cdot y_{s,c,ts} \quad (1)$$

$$\text{s.t.} \quad \sum_{ts \in T} x_{s,ts} = \ell(s) \qquad \forall s \in S \quad (2)$$

$$x_{s,ts} - \sum_{c \in C(s)} y_{s,c,ts} = 0 \qquad \forall (s,ts) \in S \times T \quad (3)$$

$$\sum_{s \in S(c)} y_{s,c,ts} \leq cap(c,ts) \qquad \forall (c,ts) \in C \times T \quad (4)$$

$$\sum_{ts \in T} y_{s,c,ts} \leq 1 \qquad \forall (s,c) \in S \times C \quad (5)$$

$$x_{s,ts}, y_{s,c,ts} \in \{0,1\} \quad (6)$$

Figure 2. Resulting integer linear program

The integer program (1)–(6) includes two kinds of binary variables – $x_{s,ts}$ and $y_{s,c,ts}$. In a solution a variable $x_{s,ts}$ equals one if and only if student s Є S has been assigned a tutorial at timeslot t_s otherwise $x_{s,ts}$ is zero. A variable $y_{s,c,ts}$ is set to one if student s Є S has been assigned a tutorial of the course c at timeslot t_s. Based on these variables we are able to formulate linear constraints specifying our version of the post-enrollment timetabling problem. In (1) the objective function is described, thereby *prio*(s,t_s) reflects the priority of the student s to have a tutorial at timeslot t_s. The goal of this linear integer program is to find a variable setting of the $x_{s,ts}$, $y_{s,c,ts}$ variables satisfying the constraints (2)–(6) and minimizing the objective function (1). The constraints (2) affirm that every student gets assigned to as many tutorials as he/she applied for. In (3) the two kinds of variables are linked. That means if the variable $x_{s,ts}$ equals one, or in other words, if the student s has been assigned some tutorial at timeslot t_s, there must be exactly one course c where student s participates in a tutorial at this timeslot t_s. To put it differently, if the student s has no tutorial at timeslot t_s (the variable $x_{s,ts}$ equals zero), he cannot be in any tutorial of other courses at this timeslot, and in consequence all the variables $y_{s,c,ts}$ must be zero. The constraints (4) safeguard that the capacity of the different courses are never exceeded. Finally in (5) the earlier mentioned bundled cuts are specified. The last constraints (6) postulate that all variables should have the values one or zero in a feasible solution.

Many problem-solution approaches of the post-enrollment timetabling problem use heuristic procedures ([6], [24], [20], [6], [25], [26]). Generally these techniques are able to provide good solutions but they are not capable to prove optimality, i.e. the user never knows if the current solution is the best one or if there exists a better one. On the contrary, approaches based on integer programming as ours are exact ([27], [28]). This means, if the problem is solved, the user can be sure that the found solution is a global optimum. This seems to be a very important feature for all users of the software. Several exact methods for solving different timetabling problems are known ([29], [30], [31], [32]), but to the best of our knowledge none of them is concerned with the post-enrollment timetabling problem.

C. *Statistics*

In table 1 some statistics concerning the development of the TUTOP specific key data are presented. We can easily see that the total number of participating users/courses has been increasing enormously for the last few years. This becomes even more apparent when we are considering the fall and spring semester separately. Another observation is that the number of tutorial spots has tripled since 2004, whereas the number of students has just doubled. This is due to the fact that for every student more courses of his current timetable are involved. In the fall semester 2004/05 every student applied for 1.65 tutorial spots on average and today is applying for 2.66 tutorial spots. Taking into account that we affirm the conflict-freeness for every student's timetable and caring for his personal preferences, this seems to be a surplus for every single student. The more courses are participating the more the students profit from their personalized automatic timetable creation resulting in a high satisfaction of the students and course offerers. The rate of approval for our work has significantly increased over the last years.

TABLE I. OVERVIEW OF TUTOP KEY DATA STATISTICS OF THE LAST FIVE YEARS

	courses	**students**	**tutorials**	**spots**	**Ø priority**	**tutorials/courses**
winter semester 2004/05	5	3270	163	5392	1.24	1.65
summer semester 2005	6	2681	149	4197	1.27	1.57
winter semester 2005/06	14	4051	326	8925	1.37	2.20
summer semester 2006	17	3569	350	8120	1.40	2.28
winter semester 2006/07	24	4507	418	11626	1.58	2.58
summer semester 2007	29	4248	461	11770	1.59	2.77
winter semester 2007/08	37	5173	540	14533	1.24	2.81

Summer semester 2008	38	4854	642	14015	1.24	2.89
winter semester 2008/09	46	5472	626	15139	1.23	2.77
summer semester 2009	46	5337	807	14032	1.29	2.63
winter semester 2009/10	54	6421	765	17073	1.26	2.66

III. IMPLEMENTATION

The MosesKonto software was implemented in Java, using a JSF [33] driven graphical user interface and using the latest web technologies within the Icefaces Java application framework [34]. The web application is running on a Java GlassFish Application Server [35] using a postgreSQL database [36].

The high adaptability and reliability of the web-based MosesKonto software induced not only a high number of users, but also an increased acceptance, especially among the course providers. This development manifested in a huge number of course providers willing to work on their administrational duties and responsibilities with the MosesKonto software. However, there is a difference between the spring and the fall semester since different courses are using the MosesKonto for creating timetables for their students. Some of the participating courses are using the MosesKonto only for the administration of written examinations. The combination of over 200 different courses (with “only” 54 of them using the software for timetabling in the fall semester of 2009/10) as well as over 22.000 individuals using the MosesKonto creates new administrational and organizational challenges for the MosesKonto. One of these challenges is the allocation of the different supported administrative tools and the private user data involved, which occasionally concerns sensible data like the results of written examinations. It was necessary to implement a user rights management system on the MosesKonto not only in order to protect the privacy of the data but also as a duty impelled by the proceeding process of decentralization When the MosesKonto was started in 2003, we created our own user management due to the lack of a centralized authorization system.

Since fall semester 2007/08 we have been using the central LDAP server (Lightweight Directory Access Protocol [37]) of TU Berlin. LDAP was originally invented to make frequently-used data available faster and more easily. It is also often used to authenticate users. Every member of the university has a central tubIT account (tubIT: IT service center of the TU Berlin), with which it is possible to use several independent services (e.g. email, WLAN), always using the same username and password.

Although single sign on frameworks such as Kerberos are used, one is not handed from one service to another service. Instead one needs to enter the username and password for each service separately. Therefore LDAP works much better than Kerberos and for a great number of applications standard LDAP modules exist. Nevertheless only one single central user administration is needed for different services.

In the near future, the MosesKonto will be integrated into the TU web portal to implement a real single sign on (with several other services offered by tubIT). Additionally, users have to be equipped with different detailed rights, depending on their role. Typically, the users of a system fall into one of the following groups requiring fundamentally differing access rights that can even vary between departments:

- Students, as a rule, are granted access to their own personal data and nothing else (exception: courses allowing team work). They are given write access for their own data and for registering for exams or exercise classes, otherwise read access only.
- The Administrator is given access to all information; he is provided with additional, special rights, such as the creation of new modules.
- Employees of the Service Center are usually responsible for all communication with the central office of examinations. The Service Center is the central contact for all students.
- Teaching Assistants are often responsible for entering the results of exams and similar tasks.
- Tutors will enter their input if the homework-related criteria are met and have access to the personal data of their students.

The growing interest of other schools in using the MosesKonto for the registration of their own exercise classes, examination and student administration outside the mathematical service modules required an expansion of the access right management to facilitate the independent administration of their students. These changes are responsible for different access right requirements for the above mentioned user groups. As a solution, we have implemented a hierarchical access rights management system mirroring that of UNIX [38]. All reading or writing rights for the different types of information and user interactions (e.g. access to the students’ personal data or to their examination results) are treated as a single, independent resource, whereas only the writing rights allow changing or submitting data. Passing these resources (reading or writing) is treated as a third type of resource. User groups (e.g. teaching assistants) can be created and are defined by their associated access rights. The owner of a group (either because he created it or it was associated with him by default) has the right to add or remove members of the group or grant access rights to group members within the limits of his own rights. Students are outside this access rights management, as their rights do not have to be defined on a per-module basis. The right to register for an exam, for example, can be managed through the use of a registration time period.

Facing the high number of courses using the MosesKonto for administrational tasks in students' management and therefore rising complexity and, more importantly, for the purpose of decentralizing the administrational duties it was necessary to develop a user-friendly and intuitive user interface for creating new resources and managing the already existing rights respectively. Therefore we created a JSF [33] driven graphical user interface using the latest web technologies within the Icefaces Java application framework [34].

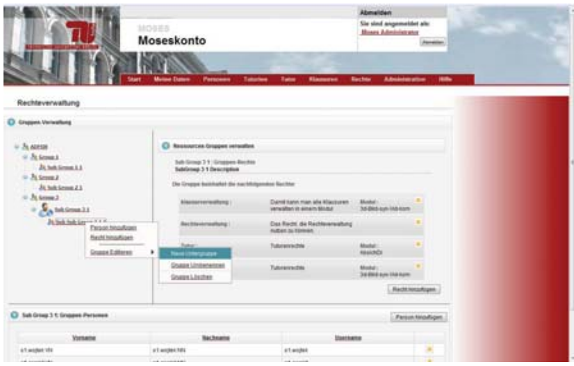

Figure 3. Tree structure of access right management

In order to be fully compatible with the webpages created in the earlier period of the MosesKonto and to keep the proven flexibility of right assignments, we stuck to the UNIX-based rights management and extended the existing three types of resources by adding a fourth type of resource, which gives the group associated to it the right of passing not only the reading or writing resource but also the right to pass this third type of resource, including the ability of passing itself. Finally, it is now possible to hand in every single task, assigned to a right, to a group of users, which again can assign it to another group or handle it themselves. Through this, the base for decentralizing the administrational tasks was created. As a next step we adopted the hierarchical structure of the rights management by arrangement of the groups in a tree structure.

If a member of an existing right group wants to create a new group now, he or she can only create it as a subgroup of the original group and pass the rights within the limits of his own rights. As a result, the tree structure develops on its own.

The new tree-structured user interface also simplifies the allocation of rights to a greater number of groups by associating all upper groups with rights associated to lower groups and vice versa. The upper groups are also able to delete or change the rights of the lower groups.

As a last step in improving the rights management system of the MosesKonto we combined the four types of resources mentioned before to a coherent group of resources.

This new created "resource-group" forms a layer of rights which, from the user's point of view, appears as an independent package of rights and can be assigned to different groups whereas the content, or more precisely the included resources, can only be controlled by the administrator.

However, one should bear in mind that these "resource-groups" are not used for verification of the given rights, but only the resources within the groups are relevant for the purpose of usage.

On the one hand this centralization of resources indeed decreases the flexibility of right allocation for the user, but on the other hand it increases the acceptance and usability of our right management system by letting the administrator combine sensible resources and give them meaningful and significant names and descriptions.

IV. OUTLOOK

The rapidly increasing number of courses using our tool motivated our group to develop more software solutions for different timetabling problems. We have recently finished the implementation of a tool which creates examination timetables for a huge number of written exams affirming that the students have enough time for preparation between two exams [39].

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Enhancing Database Querying Skills by Choosing a More Appropriate Interface

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Abstract – **To benefit from data stored in growing numbers of database systems, the number of users capable of finding relevant information should also grow. They should be capable of posing requests, formulate relevant queries, and interpret the obtained results. The user interface should allow them to concentrate on the core of the problem without disturbances caused by details of the query language's syntax. We show the results of our study of the relationship between the interface offered by query languages and their users' ability to express their requests in a correct and comfortable manner. Our aim was to analyze the state-of-art in introductory database courses from this point of view, to design and to test an educational methodology appropriate for non-professionals. It should help them to achieve an advanced expertise in query design and development.**

All DBMS's contain SQL but many of them also have a version of Query-By-Example (QBE) language. Their developers likely believe that for non-professionals this sort of interface is more appropriate for creating queries than SQL. Our review of literature showed that the topic was hardly studied in depth. To do so, we designed and developed an educational methodology which addresses the frontier field between design of query languages, HCI, users' mental and conceptual models and performed an educational experiment that tested it.

Many of our presumed advantages of QBE have been proved correct. There are statistically significant differences in time, accuracy and users' satisfaction related to query creation. We also found out statistically significant differences in combinations of variables (time, accuracy, and satisfaction) and the level of task difficulty. The result may have a positive influence on non-professionals' exploitation of databases. It may lead to designing and developing a combined methodology that would benefit from positives of both: QBE and SQL.

Keywords- introductory database courses; comparison of QBE and SQL; query formation; mental models of query processing.

I. Problem Statement

The amount of data stored in database applications is constantly growing. To benefit from them, the number of users capable of finding and benefitting from them should also grow. Many of those search activities have been programmed, but new and new questions always arise. For that reason the database users should be capable of posing their requests. The users should be capable of recognizing whether they are solvable within the given database, formulate relevant queries, and interpret their obtained results. These issues are of a distinct importance for non-professionals in ICT as the query creation is for them just a tool for achieving their professional information. The user interface should allow them to concentrate on the core of their expert problem without disturbances caused by details of the query language's syntax. Thus, questions like the next ones can be posed: *Which query language satisfies the non-professionals' expectations the most? How to measure the effects of a query language to its users? What methodology to apply and how far to go in their training?*

In this paper, we show the results of our study that analyzed the differences between SQL and graphical Query-By-Example (QBE) in order to get relevant answers. We concentrate on distinctions that enhance learning processes of ICT non-professionals, and analyze the user's ability to express their requests in a correct and comfortable manner.

II. Purpose of Study

The choice of the background languages for our study was quite natural. SQL is a standard for database management systems (DBMS). Many of them also introduce their own semi-graphical version of the Query-By-Example language, often labeled as a QBE-like language (thereinafter QBE). Developers of DBMS likely believe that this sort of interface is more appropriate for casual and non-professional users. Nevertheless, our examination of literature showed that the topic was hardly studied in depth.

As similar considerations represent a frontier between design of query languages, computer-human interface, and users' mental and conceptual models, we designed an educational methodology which reflects all of these aspects and does not depend on a particular query language. Based on the methodology, we developed two parallel courses of query design and development. The first one follows the classical approach based on SQL. The second one also exploits the advantages of QBE. The methods were used in two parallel classes of the same *Introduction to Databases* course.

Three hypotheses were specified. They addressed speed, quality and comfort of query creation in the two languages. In all of them, we favored QBE i.e. we presumed that the users of

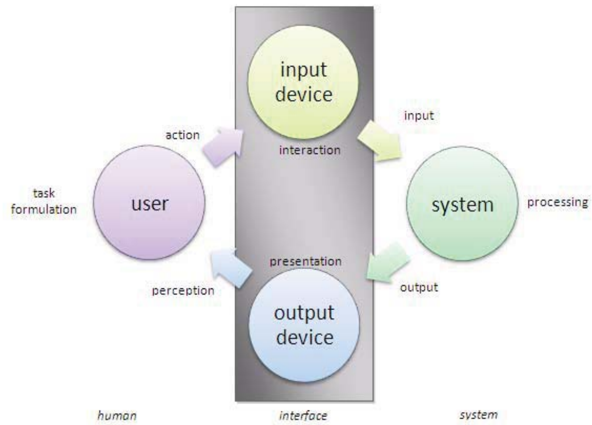

Figure 1. Basic cycle of interaction by Abowd [1].

QBE will be more successful in all three dimensions than users of SQL. Then, a pedagogical experiment was performed – the test group was using our new approach using QBE while the control group used the more traditional SQL.

III. Interaction Models

The human-computer interaction has been the key issue in designing our educational methodology. Here, "humans" mean database end-users, non-professionals in ICT. Our aim is to teach them query creation to the degree in which they can interact with their database applications and gain answers to their questions. Accordingly to Abowd [1], the interaction is executed in the way indicated in Fig. 1. Notice that the differences between QBE and SQL only address its "upper left corner". The rest is virtually identical for any query language because:

- The evaluation of the queries is hidden from the users;
- The presentation of the results does not depend on the used input language. In the same DBMS, it is identical for both of its query languages.

For that reason, the conceptual model of the interface, the user's mental model of this interface, and the query notation are the only factors playing key roles in the communication [2]. The conceptual and mental models are important for the design of human-computer interaction, as well as during users' learning. In a badly-designed conceptual model, confusing interaction can make the solution of the users' task more complicated. The learners with wrong mental models will meet with troubles during forming queries that should answer their requests. Oppositely, well designed interaction simplifies the problem solution on one side, and the creation of learners' mental models on the other one. The users' success rate and, consequently, the popularity of the query language will grow. Some sources [2], [3] indicate that these topics have been neglected by researchers. Nevertheless, we feel inevitability to explain the relevance of their research to our own one.

Prior to that, we introduce our terminology.

A. *Conceptual Model of the Interface*

For designers, the interface represents a communication channel between front and background activities. It transfers messages between the system and the user. The communication is based on so-called *conceptual model*, i.e., the general framework in which the data and information move between the front-side (visible, operated by the users) and back-side (invisible, executed by the DBMS).

The conceptual model represents the DBMS's functionality. It is preprogrammed. The experienced user's internal (mental) model of this functionality coincides with the conceptual model well. That's why the experienced users are capable of exploiting the features of their DBMS much better than non-experienced ones despite the fact that both categories communicate with the same conceptual model.

B. *Learner's Mental Model*

The main aim of education is to build proper mental models in the minds of learners. Their future mental models should become close equivalents of the conceptual model of the interface they are trained to use.

Every learner exploits his/her mental model to reason about the system, to anticipate its behavior and to comprehend why it reacts as it does [4]. During learning, each and every learner forms his/her individual model with his/her own internal objects and specific ways of understanding of how the computerized processing works. These models may not fully coincide with the conceptual model [5].

From the designer's point of view, the user and the system are "two partners of the same importance". From instructor's point of view, the conceptual model is "done" (i.e. static), whilst mental models are formed (i.e. dynamic) [5]. The educators are therefore supposed to familiarize their students with the conceptual model in a stepwise manner and verify to what degree their mental models match the reality.

In general, people are not very good at constructing and understanding our own mental models or using them for decision making. So, it is difficult to measure the "distance" between people's mental models and the conceptual model. On the other hand, for day-to-day purposes it is sufficient, if the learner's metaphors and analogies lead to their adequate control of the system. Due to that, the mental models we use are often extremely simple.

The mental models have some powerful advantages. They are flexible – they can be adapted to new situations and be modified as new information becomes available. But mental models have their drawbacks also. They are not easily understood by others; interpretations differ person to person. The assumptions they are based on are usually difficult to examine. As a result, ambiguities and contradictions within them can go undetected, unchallenged, and unresolved.

Also, learning never starts from scratch as each of us already owns many mental models. In truth, "*our decisions and actions are based not on the real world, but on our mental images of that world, of the relationships among its parts, and of the influence our actions have on it*" [5]. During the process of their learning, the computer users have to form their own models and to learn to work with them [6]. This also runs during learning of query creation. The role of teaching methodologies is to split the process into „edible chunks“. Each of them shows a small portion of the conceptual model and creates an additional piece of his/her mental model. These individual mosaics (as well as their previous experience with creating their mental images) are composed in the students' heads into their final mental models.

From the point of view of education, such an approach has one advantage. The educator can formulate "an optimal mental model" and build a methodology aimed to it. This so-called *target mental model* specifies the knowledge the students should get in the end of their learning processes. If there is a difference between the concrete mental model of a student and the instructor's target mental model, the instructor can (a) redesign their communication and/or (b) use other learning materials to enhance the transition from the student's current model to the target one [7]. Actually, this idea did motivate us to replace the traditional SQL-oriented courses to QBE-oriented ones as we felt that the former ones are not appropriate to achieve our target mental model (and consequently, the depth of knowledge) we would expect among non-professional users.

Learning is a back-loop process and its run can be illustrated as follows (Fig. 2):

- *Single-loop learning* is shown in the upper part of the picture. Every person has a stockpile of mental models for standard life situations. When we make a decision and then perform its relevant activity, feedback from the real world gives us information on whether our decision brought the desired effect or not. When the feedback is positive, it reinforces our mental model. In such cases, our aims may change, but our mental model remains the same. It is our dominating method of acting; it is simple and convenient. Once the mental model is fixed (and the responses from the real world coincide with our presumptions), our decisions are coming quickly.
- When the feedback from our environment is negative, *double-loop learning* is necessary. This process covers the entire figure. The negative feedback indicates the necessity to change our mental model. Unlike single-learning loops, this model includes a shift in understanding – from the simple and static one to a broader and more dynamic one. We start taking into account the changes in the surroundings that might cause our mental model's imperfection and try to include them as another piece of mosaic [8]. School education is built on continuing challenges to students' current mental models. Teaching methodologies represent recommended strategies guiding the educators and helping them to facilitate transitions from their current mental models to the targeted ones. Notice that there can be several methodologies describing parallel roads from the given mental model to the identical target.

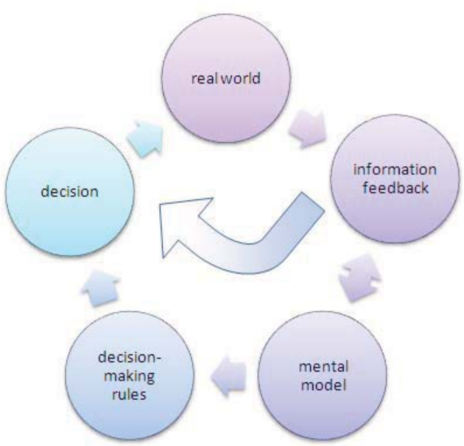

Figure 2. Double-loop learning [7].

C. *Query Creation Target Mental Model*

Our group of learners consists of future non-professionals in ICT. For that reason, the exploitation of databases is not their main aim; it appears as a part of a more general task. Consequently, the target mental model discussed in our paper is composed of the following pieces of knowledge:

1. *Formulation of a question* that can be answered by the means of a given database. As the question mostly appears as a part of a practical problem, it is formulated in a natural language.
2. *Feasibility of the solution* must be discussed. For example, the user must make certain that the addressed database contains all necessary data – otherwise the problem is not solvable and, consequently, there is no reason to open the query creation process.
3. *Transformation of the question* formulated in a natural language to a semantically-equivalent query written in a query language.
4. *Execution of the query* over the database.
5. *Interpretation* of the gained results.

The time allocated to databases in curricula is constant and limited; the proposed methodology must respect these boundaries. For example, the first and the fifth part might be "too specific" and strongly depending on an application field. As our group of learners has not a unified field of study, we overcome this problem by forming a wide range of application databases referring to popular fields like libraries, travel agencies, transportation, personal records, etc. Due to that, we can presume that all students have sufficient prerequisite knowledge and experience to formulate and solve relevant problems of "any" difficulty.

Our methodology is a reflection of Reisner's principal model [3]. Despite its age, the model is still relevant as the structure of databases and their interface has not changed substantially since. In her model, users' performance is determined by the time it takes to think about proper query design, to writ the query as the DBMS input, and to correct various types and numbers of errors. The thinking effort is what Reisner calls the *selection of an appropriate template*. From the point of view of time sequence, the process of query creation consists of two basic templates [9]:

(a) Understanding of the problem and its relation to the database structure;

(b) Formulating a correct syntactic construction that will produce the problem solution.

In detail, the problem consists of the following activities [9]:

- *Understand instructions*: The user must comprehend the instructions that describe the query task to solve the query correctly.
- *Construct deep structure*: The deep structure of a query task is a complete and thorough comprehension of which data must be retrieved from the database and how the result data must be structured. The deep structure of a query task is independent on the used query language.
- *Construct surface structure*: The surface structure of a query task is a query language expression that is a translation of the deep structure. If the user is satisfied with the query expression, he/she submits the query to the processor. When the user is not satisfied with the outcome, he/she makes correction efforts or tests.
- *Submit query*: The user submits the query language expression to the query processor.
- *Evaluate result*: The user reads and tries to interpret the information that he/she received from the query processor. This information may contain an error message or resulting record set (which itself can be correct or wrong).
- *Correction effort*: When the query was not processed or produced a wrong outcome, the user tries to understand the type of error and fix it.
- *Test expression*: The user supposes that the query is correct but makes its additional runs using modified data sets in order to verify its correctness in a more general manner.

The traditional target mental model includes SQL as a carrier for query creation. The reason is quite logical. SQL is a standard component of databases. Thus, the learned knowledge is widely applicable. On the other hand, SQL is a typical programming language with a very formal syntax. As such, it is strict and not well-legible. That's likely why designers of database management systems often introduce a parallel notation named Query-By-Example (QBE).

As SQL is a carrier, it is a substantial but not the decisive element of the target mental model. Moreover, a dependence of a methodology on a particular programming language is not a sign of its high quality. Thus, questions arise: *Can SQL be replaced by QBE? To what degree will the replacement be successful?*

We believed that SQL is too formal for casual and non-professional database users. For that reason we decided to reflect our considerations in the design of a new *Introduction to Databases* course. From one side, it would address the same target mental model as the traditional SQL-based courses do and, from the other side, it would exploit QBE as the query carrier.

To evaluate its effectiveness we designed a pedagogical experiment. The database course was prepared in two versions using the identical educational methodology. Fig. 3 shows its structure. Its third block was delivered in two versions – the traditional one using SQL and the newly developed one based on QBE. The pretest and posttest served for measuring the students' knowledge in the relevant classes (with QBE-class as the tested group and the SQL-class as the control group).

IV. RELATED WORKS

The relation between SQL and QBE was studied many times. Whilst SQL has its standard definition, there are many DBMS-specific versions of QBE. In our paper, we consider its form-based version in Microsoft Access as it was the tool used in our classrooms.

Former experiments comparing the two paradigms did not bring definite evidence on a statistically relevant difference between the effectiveness of their application [10]-[16]. Some of these unambiguous conclusions are presented in the comparative articles [3], [17]-[19]. In accordance to them, both languages require equal capability of abstract thinking and complete specification of the way from the input data table(s) to the output list of results. More recent papers targeting so-called visual query languages analyze different level of abstract thinking that the users of DBMS should have to accomplish their tasks [10], [16]. We have not found a study that would describe research on educational aspects of a graphic-form version of QBE and SQL that would represent an analogy to our study, except in [20].

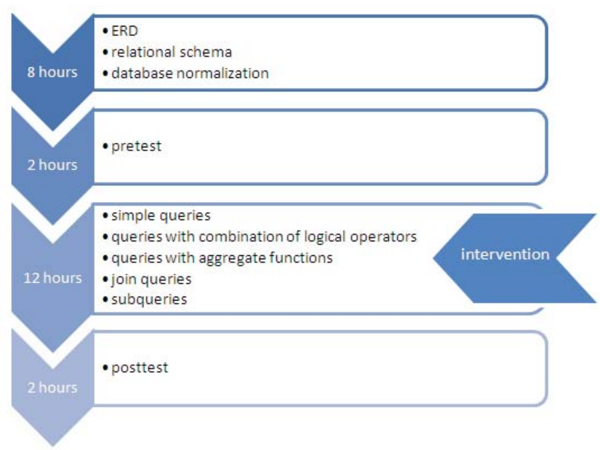

Figure 3. Timeline of the experiment.

V. Research Method

As Fig. 3 shows, the experiment was done during 24 hours of lecture in one semester. The figure also shows its stages. It has the form of a pedagogical experiment with pretest, posttest and two groups – experimental (tested) group and control group.

The design of our experiment followed the standard methodology and its outcomes were statistically evaluated. Its principal steps were as follows:

- Formulation of research hypotheses.
- Creation of experimental and control groups.
- Reliability/Item Analysis:
  - Estimation of reliability of the questionnaire and test.
  - Identification of items that might degrade its relevance and fixation of the problem.
- Execution of the experiment:
  - Simultaneous application and evaluation of the pretest in both groups.
  - Parallel run of courses in the groups.
  - Simultaneous application and evaluation of the posttest in both groups.
- Statistical analysis of the results.
- Interpretation of the results.

A. Target Group

The total number of students participating in the experiment was 116 divided into two groups:

- QBE – 59 students,
- SQL – 57 students.

The groups were formed from the students of the same year-class and were equivalent from the points of view of their age, gender and previous study results. The level of their knowledge was also verified during the pretest and confirmed our presumption on the group equity ($p = 0.330751$).

B. Dependent and Independent Variables

To formulate and verify hypotheses, one needs their variables. The independent variables are query tasks of five difficulty levels to be implemented using two query languages – SQL and the MS Access version of QBE. They represent independent variables in our experiment.

To study which of these tools is more appropriate for our target group the analyzed factors should express their appropriateness for their users. The studied factors were the users' performance and overall satisfaction with this activity.

1) Performance

Performance was measured using two parameters: correctness of the solution and the time for its accomplishing.

The correctness of query is its critical feature. It can be expressed as difference between the presumed (exact) solution and the one produced by the learner. In our evaluations we used the "Correct-Incorrect" scale where the queries semantically equivalent to the right answer (i.e. those always producing the same set of records) were characterized as the "Correct" ones.

Time for completion of the query was the second parameter. Time was measure for each query individually. The student could choose any test task to solve but he/she could not work on two or more tasks simultaneously. Thus, the gained values expressed the time periods each student spent on every of his/her solved tasks.

2) User's Satisfaction

Any software tool will succeed if and only if its users are happy with it. It can be expressed by user's opinions collected using a questionnaire. As personal opinions are rather subjective, 9-point Likert scale was applied in order to quantify their feelings on a numerical scale.

C. Reliability of Test and Questionnaire

In the case of didactical test, the value of reliability coefficient is to be 0.83 (83 %) and expresses the ratio between the sum of variability of individual task's score and the total variability of the test. The used estimations (*Cronbach alpha* = 0.83; *Standardized alpha* = 0.85) are satisfactorily close so one can presume the equal variability of the tasks i.e. no suspicious tasks were identified. All tasks were in correlation with the overall score and their removal did not affect the reliability coefficient. Thus, our selected tasks did not decrease the test reliability.

An identical approach was applied the questionnaire with similar results. In particular, the ratio between the sum of variability of values of individual questionnaire's item and the total variability of the questionnaire was 90%.

As the result, both instruments were claimed to be highly reliable.

D. Hypotheses

Three research hypotheses have been formulated:

- The members of the group using the graphic interface QBE will complete their solutions faster than the members of the group using SQL.
- The members of the group using the graphic interface QBE will produce more exact solutions than the members of the group using SQL.
- The members of the group using the graphic interface QBE will be more satisfied with their solutions and the way they were achieved than the members of the group using SQL.

The first two hypotheses were tested using a posttest consisting of the query creation and identical for the both groups. The third one was verified using the questionnaire.

E. Groups of Query Tasks in Experiment

The majority of analytical work comparing a query language towards SQL addressed selection queries i.e. the ones beginning with the keyword SELECT [11], [15], [16], [21]. For that reason we also concentrated on the same problem group.

In order to measure the users' cognitive efforts required for their task solutions, we split the tasks into five levels of difficulty. The criteria for the distribution were type of the query, complexity of the conditions the records have to fulfill, and the number of tables the query must include. Their order expressed their complexity starting with the simplest ones:

- *G*1: one table, a single condition and/or sorting of records,
- *G*2: several tables, a single condition,
- *G*3: combination of records from several tables,
- *G*4: aggregation of values stored in one table,
- *G*5: nested queries and subqueries.

The number of queries in the posttest was partially influenced by its presumed duration (90 minutes). For that reason, it consisted of 20 problems written in a natural language. The number coincides with the amounts of tasks mentioned in similar experiments [11], [13].

VI. Results

The results of the experiment were analyzed using linear models.

A. Verification of the Hypotheses

The hypotheses were analyzed using the one-way analysis of variance.

Our first hypothesis stated that the students applying QBE-based approach will need shorter time for query formation. The hypothesis has been proved ($p = 0.000383$).

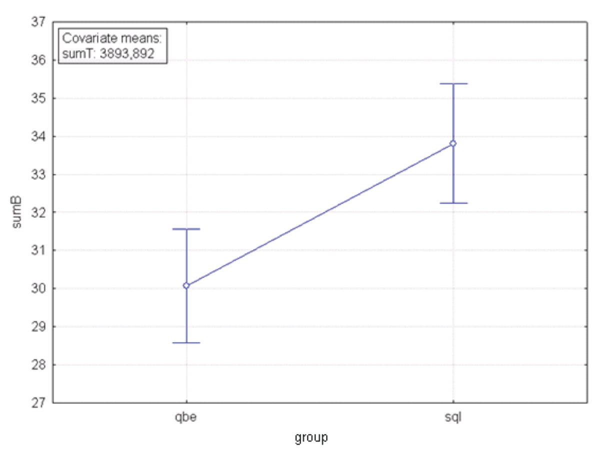

Figure 4. The means with error plot showing the correctness of the solution with respect to the mean time required for its creation.

The second hypothesis stated that the QBE students will create more accurate queries than those using SQL. This hypothesis was not confirmed. The quality of students' queries was almost identical in both groups ($p = 0.516098$).

The third hypothesis presumed that the QBE students will feel better comfort during their query creation and higher satisfaction with their results. This hypothesis has been confirmed ($p = 0.000515$).

B. More Detailed Results Related to Time Periods Required for Query Creation

The verification of the first hypothesis has proved that QBE queries have been made faster. To achieve a more detailed picture, we decided to include another factor – the time period necessary for the query completion. The analysis of covariance showed another statistically significant difference. It differed from our expectations. In accordance to it, if the time for the solutions would be identical, the SQL group responses would be more accurate. Fig. 4 shows the estimated means with the respect to the correctness of the query and time.

Based on data in Table 1, the zero hypothesis – the presumption that there is no statistically significant difference between the groups in the precision of the query formation – was rejected at the 99% confidence level. It shows that the relation between the covariate – the variable *sumT* (total time) – and dependent variable *sumB* (total score) – is statistically significant at the 0.01 level.

TABLE I. ANCOVA, UNIVARIATE TESTS OF SIGNIFICANCE FOR THE CORRECTNESS OF THE QUERY CREATION

	SS	*df*	*MS*	*F*	*p*
intercept	22703.16	1	22703.16	718.4995	0.000000
sumT	2217.19	1	2217.19	70.1685	**0.000000**
group	351.54	1	351.54	11.1253	**0.001168**
error	3412.59	108	31.60		

Meaning of the terms: SS = adjusted sum of squares, df = degrees of freedom, MS = adjusted mean square, F = mean square ratio, p = p-value (the probability of the observed data when the null hypothesis is true), intercept = the parameter in an equation, sumT = continuous independent variable (covariate), group = categorical independent variable, error = residual error.

TABLE II. ANCOVA, UNIVARIATE TESTS OF SIGNIFICANCE FOR THE OVERALL SATISFACTION OF THE USER.

	SS	*Df*	*MS*	*F*	*p*
intercept	778.8507	1	778.8507	595.6569	**0.000000**
sumT	24.9029	1	24.9029	19.0455	**0.000028**
group	6.4686	1	6.4686	4.9471	**0.028121**
error	147.7531	113	1.3075		

Meaning of the terms: SS = adjusted sum of squares, df = degrees of freedom, MS = adjusted mean square, F = mean square ratio, p = p-value (the probability of the observed data when the null hypothesis is true), intercept = the parameter in an equation, sumT = continuous independent variable (covariate), group = categorical independent variable, error = residual error

Similarly, the covariance analysis demonstrated a statistically significant difference between the groups even if the time is taken into account (Table 2). The zero hypothesis stating that there is no statistically significant difference between the groups when the time is taken into account could be rejected at the 95% confidence level.

It also shows that the relation between covariate *sumT* a dependent variable *vpS* (overall satisfaction) is statistically significant at the 0.01 level. In this case, the analysis of covariance ($p < 0.05$) confirms the results of the analysis of variance ($p < 0.01$).

C. Comparison of the Groups of Variables

The most interested results have been generated by ANOVA repeated measures. They helped us to show statistically significant differences between combinations of variables (time, accuracy, and satisfaction) and the level of task difficulty. Here, the division of problems into the categories *G*1-*G*5 played its role, too.

Tukey HSD test (Unequal *N*) allows us to analyze the relationship between the categories of tasks separately in the test and control groups. The detail results exceed the presumed size of our contribution. Therefore we prefer visualizing our outcomes in Tables 3-5 and Fig. 5-7.

1) Time Duration

The natural presumption that the more difficult tasks require more time to solve has been proved. Fig. 5 indicates the statistically significant differences between periods necessary for the query creation and selected combinations of time and category of the task. Each line corresponds to one of the groups.

The principle contribution of the next analysis consists in the identification of differences in query creation in the individual groups. In our particular case, the diagonal values are the most interested as they express the comparisons of the time periods. Naturally, we want to know the comparisons of time periods spent on the same tasks.

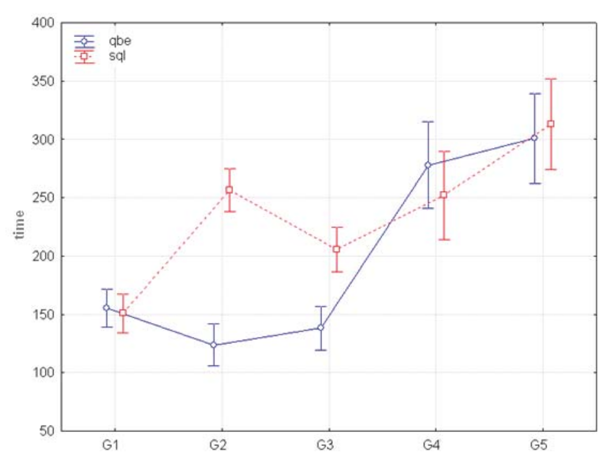

Figure 5. Categorized means with error plot for repeated measures of time periods.

There are larger differences between the groups *G*2 a *G*3 (Table 3): 0.005693 in the former case, 0.611760 in the latter. A statistically significant difference ($p<0.01$) has been proved in the case *G*2. It implies that the time for creating QBE queries with a single condition in multi-table databases is significantly shorter than that of similar queries in SQL. There was also an observable difference between the *G*3 tasks (aggregated queries) but it was not statistically significant (*G*3).

TABLE III. MULTIPLE COMPARISONS FOR TIME COMPLEXITY

Group (QT)	***SQL(G1)***	***SQL(G2)***	***SQL(G3)***	***SQL(G4)***	***SQL(G5)***
QBE(G1)	1.000000	**0.000032**	0.272150	**0.000073**	**0.000012**
QBE(G2)	0.940429	**0.005693**	**0.001846**	**0.000012**	**0.000012**
QBE(G3)	0.999810	**0.000013**	0.611760	**0.000013**	**0.000012**
QBE(G4)	**0.000012**	0.988066	**0.011454**	0.999009	0.763889
QBE(G5)	**0.000012**	0.445651	**0.000093**	0.303231	0.999998

Meaning of the terms: QT = query type

2) Precision of Solutions

There is a statistically significant difference between the precision of solutions in the student groups. The zero hypothesis stating that there is no significant difference was rejected. We would see the strong relationship between the precision of the solution and the task difficulty – see Fig. 6. The picture indicates a difference between some problem groups – in particular *G*1 and *G*3 – but they are not statistically significant (see Table 4).

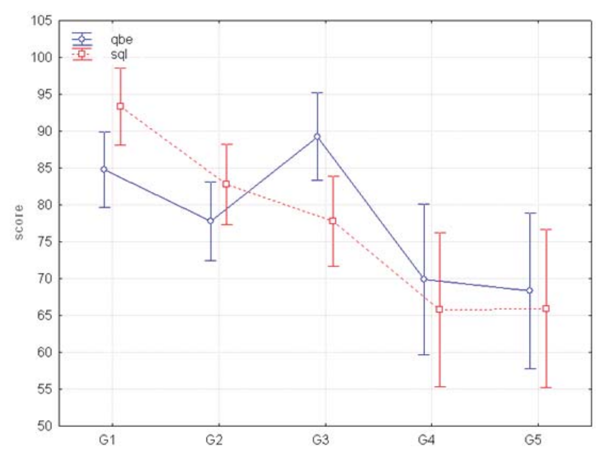

Figure 6. Categorized means with error plot for repeated measures of precision of solutions.

TABLE IV. MULTIPLE COMPARISONS FOR PRECISION OF SOLUTIONS

Group (QT)	***SQL (G1)***	***SQL (G2)***	***SQL (G3)***	***SQL (G4)***	***SQL (G5)***
QBE (G1)	0.992792	0.999999	0.968587	**0.029521**	**0.032071**
QBE (G2)	0.161187	0.999906	1.000000	0.519844	0.538235
QBE (G3)	0.999431	0.981135	0.948587	**0.001530**	**0.001701**
QBE (G4)	**0.001595**	0.411372	0.932978	0.999982	0.999524
QBE (G5)	**0.000509**	0.247468	0.820548	0.999988	1.000000

Meaning of the terms: QT = query type

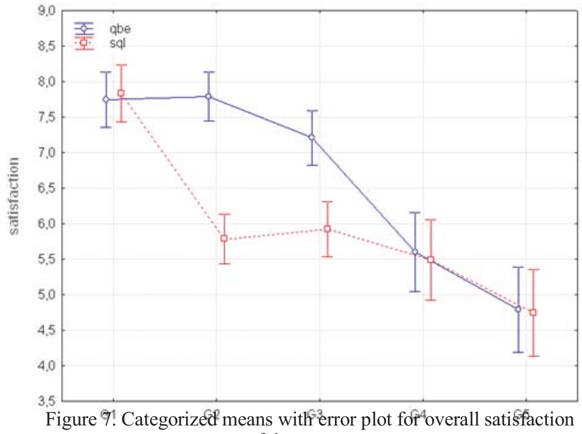

Figure 7. Categorized means with error plot for overall satisfaction of the user.

3) *Overall Satisfaction of Users*

Finally, we focused on the relationship between overall satisfaction of the users and the query type. Overall satisfaction of end-users is decreasing while query complexity is increasing.

One could anticipate this effect – its relevance to the subjective nature of this variable is obvious. If the end-user has to make greater effort to understand the merits of the task and used interface that does not offer sufficiently simple solution, his/her satisfaction would be on decline.

At the same time, the reader of the values on table diagonal comes to the findings that there is a statistically significant difference between overall end-user's satisfaction and different types of queries. There are apparent differences in overall satisfaction of the user in favor of QBE-like graphical user interface in tasks from the groups *G*2 and *G*3 (Fig. 7). A statistically significant difference ($p < 0.05$) has been proved in the case *G*2 (Table 5).

TABLE V. MULTIPLE COMPARISONS FOR OVERALL SATISFACTION OF USER

Group (QT)	*SQL(G1)*	*SQL(G2)*	*SQL(G3)*	*SQL(G4)*	*SQL(G5)*
QBE(G1)	1.000000	**0.000013**	**0.000015**	**0.000012**	**0.000012**
QBE(G2)	1.000000	**0.015005**	**0.000014**	**0.000012**	**0.000012**
QBE(G3)	0.697302	**0.001091**	0.380372	**0.000028**	**0.000012**
QBE(G4)	**0.000012**	0.999945	0.994973	1.000000	0.255619
QBE(G5)	**0.000012**	0.095280	**0.028524**	0.547970	1.000000
			Meaning of the terms: QT = query type		

VII. DISCUSSION

We have prepared our paper as our contribution to the research of interaction between database end-users and relational database systems. In particular, we have been interested in comparing two interfaces designed for query formulation and to the problem of the future end-users training.

In order to identify the differences, we used one-way analysis of variance and analysis of covariance for solving of our research problem. One-way analysis of variance is simpler and it does not require the fulfillment of assumptions about regression in individual groups. On the other hand, if there are some differences in controlled variable between groups, its interpretation is less valid. Therefore it is recommended to realize both analyses and compare their results.

The results of experiment could have been affected by several factors. We must mention the process of participants' selection first of all. Our participants were students of the preliminary database courses. For sake of completeness of our statement, we have to add that the characteristics of students may differ in some details from typical end-user in non-academic environments. On the other hand, our approach is supported by several scientific papers from this research field [13], [15], 19], and [22] that applied a similar approximation of the term "end-user".

The second factor is the number of the participants in experimental and controlled group. Although it may seem sufficient, it is evident that we would become more general results if we could repeat experiment with greater number of participants and/or more than once time. We could not afford such numbers considering (a) the size of our institution (b) regular changes in the syllabus that exclude prolongation of the identical content over several consecutive years.

The different complexity of the tasks is another factor that might have effect on the experimental results. From the very beginning, we understood that tasks leading to subqueries may affect the overall reliability of some results of our test. They are much more complex than other four types of tasks. Their extreme complexity could therefore affect the overall end-user's satisfaction. As they are very frequent in day-to-day situations, we decided to include them to the test despite the above reservation.

We cannot forget in this discussion the limited duration of individual tasks as well as entire testing procedure. Although we took sufficient free float for each task, the clock displayed on the screen could have affected participant's activity and disturbed his/her overall satisfaction.

VIII. CONCLUSIONS AND FUTURE WORK

It has been experimentally confirmed that our methodology of query formulation brings several positive outcomes. These findings could act as an impulse for further considerations about database querying and the ways of their teaching and learning.

The main positive results is proving that the QBE graphic interface allows faster and more comfortable writing of low and medium difficulty tasks compared to the SQL text-based environment does. In these cases, the accuracy of produced queries remains comparable and the comfort of QBE users is higher. One can presume that the students will build their stronger attitude to the tool that allow them faster and more comfortable work i.e. they will tend to use it even in the cases when they would try to avoid SQL.

These results may have a positive influence on non-professionals' exploitation of databases:

a) Due to their quick progress in query creation, they might become higher motivated in further improvement of their knowledge and, consequently, in their more effective and efficient exploitation of their databases.

b) Design of some (very complex) queries via QBE is difficult, if not impossible. The non-professionals should be encouraged to recognize the limits of their expertise and ask ICT professional for their assistance.

Despite the fact that not all of our hypotheses have been confirmed, many of intuitively presumed advantages of QBE have been correct. This should motivate educators to design and develop a combined methodology that would benefit from the positives of both: QBE and SQL.

The research of database query languages and especially visual query languages for end-users has an interdisciplinary character that should teachers take into account in their training as well as pedagogical research. To inspire them, we identified some interesting open questions that might be included into future research:

- What are main trends in end-user database languages? In particular, what perspective do visual languages for query formation have? To what degree can end-users successfully tackle their tasks without being familiar with the internal structure of databases?
- To what degree the interfaces based on natural languages will change the situation? What will be their advantages and drawbacks compared to the form-oriented languages?
- Do contemporary languages oriented to the conceptual design of databases have a potential that would enhance end-user participation?
- Is it possible to integrate advanced features of distinct query languages into one interface that would benefit of each of them?
- Is it possible to create an intuitive interface that would allow mining of information from distributed heterogeneous databases? How to protect the users from getting lost in such environment?

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State-of-the-art simulation systems for information security education, training and awareness

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Abstract—**This paper describes state-of-the-art simulation systems designed for information security and information assurance education, training and awareness. Being people the weakest link in the implementation of any security policy, it is of paramount importance to strengthen that link before it gets broken. The best way of improving the reactions of any person when security is attempted to be compromised is by providing him/her with better education, attractive practical training and raising the general awareness on information assurance.**

Keywords—information security; information assurance; network simulation; education; training; awareness.

I. Introduction

Information security has become one of the main priorities for governmental and private institutions. It has been shown in several occasions that a big amount of all security incidents is caused by human errors such as system misconfigurations, security policy breaches and careless systems administration. Since these actions were not done on purpose, most of them could have been avoided by improving the information security education of managers, the training of the system administrators and the general awareness of end users. Simulation systems are of great help for this task since they allow hands-on experience and user interaction. This sentence, attributed to Confucius, and also mentioned in [1], is self explanatory: "I see and I forget, I hear and I remember, I do and I understand".

This paper describes the results of a research on state-of-the-art simulation systems for information security and information assurance education, training and awareness. As first stage of the research, several of those systems have been identified and studied. The second stage makes an initial attempt to construct a taxonomy of the found simulators, following the one proposed by Saunders [1, 2] in which five distinct categories of simulation for information security are defined and described:

1. PacketWars
2. Sniffers + network design tools
3. Canned attack/defend scenarios
4. Management flight simulators
5. Role-playing

The found simulation tools have also been classified attending to their target audience, usability, learning curve required, level of detail, scalability, the possibility of being remotely used, etc.

The rest of the article is structured as follows. In section 2, brief descriptions on the research and on each of the found tools are provided. In section 3, the results of the proposed taxonomy are presented. Finally, the conclusion and possible future research are offered.

II. State-of-the-Art Simulation Systems

The current research has been performed by looking up different sources such as: IEEE magazines, IEEE Xplore Digital Library, ACM Digital Library, ISI Web of Knowledge, SpringerLINK Book Series, Google Scholar, Scientific Commons, Scirus, RefSeek or Scitopia, among others. Overall, more than one hundred references including journal and magazine articles, conference proceedings, technical reports, thesis reports, book sections, computer programs and web URLs have been obtained, classified and reviewed.

While other state-of-the-art reports on information security simulation focus on different aims of such simulations, the authors have special interest on information assurance and on the activities that allow transmitting the corresponding knowledge to the students. They have experience in both the education and private sectors in subjects directly related to information security. Within the University environment, the educational experience is directly related with grade and post grade subjects in Computer Science Engineering and Industrial Engineering at the Spanish University for Distance Education.

The education on information security subjects at University, when available, is most of the times mainly focused on theoretical issues. However, without an adequate practical teaching of information assurance matters, we are leaving the students with a weak knowledge that is not yet consolidated. The use of a security laboratory and/or a simulated network scenario is very beneficial as a mechanism for supporting active learning strategies such as: learning-by-doing, learning-by-example and learning-by-exploring.

While other forms of getting to the objective of simulating network security situations could also include adaptations, modifications or extensions to generic network simulators, in this article we have chosen to focus on the tools that are specifically designed having information security in mind. Nevertheless, some of these generic simulation tools and a description of their use for information security teaching can be found at: OPNET Modeler [3], OPNET IT Guru [4], OMNET++ [5] and ACME Studio [6].

Some of the analyzed tools are not specifically designed for an autonomous learning of information assurance aspects but are anyway included because they can be used to demonstrate certain concepts to the students even when the intervention of the trainer will be required in all cases.

Among all the simulation tools found during the research we are highlighting the following ones:

*A. **CyberProtect**, developed by US DoD's Defense Information Systems Agency (DISA) in conjunction with several entertainment software companies [7].*

CyberProtect is an old product. It has not been revised since July 1999. The product received several awards on its creation year: 1999 NewMedia Gold INVISION Award (Best Overall Design), 1999 NewMedia Gold INVISION Award (Technical Training) and 1999 International Cinema in Industry (CINDY) Competition Silver Award.

In spite of not being modified since 1999, the principles that guided its creation are still valid and the application is still fully functional. CyberProtect version 1.1 can still be obtained on CD from the Information Assurance Support Environment (IASE) of the US DoD's Defense Information Systems Agency (DISA) [7].

CyberProtect was developed as a training aid for novice network security professionals to familiarize them with information systems security terminology, concepts, and policy. It is an interactive computer network defensive exercise that provides the users with the opportunity of configuring network security features and running them against real world network security attacks. The users face a variety of security threats and must make practical decisions for allocating resources using the elements of risk analysis and risk management. CyberProtect simulates a complete fiscal year lifecycle of a simple computer network divided into four sessions. After each session, the user receives feedback on his/her performance. At the end of the last session, users are given a report detailing their cumulative scoring classifying the attacks by origin, type, and effectiveness.

*B. The Military Academy Attack/Defense Network (**MAADNET**) simulation designed by the Department of Electrical Engineering and Computer Science, United States Military Academy [8].*

The aim of this application is to simulate diverse aspects of building and managing an information system and combining them into an information assurance learning environment. MAADNET is built on a client-server architecture using the discrete events simulation (DES) paradigm. The user starts building a network on the client side in accordance with a given scenario that is then submitted to the server which will simulate different events. The user can build the network, enforce policies and employ more administrators. After that, several scenarios can be executed against the designed network in order to see how it behaves when attacked. After the simulation, the built network is evaluated in order to assess how well security was maintained.

The simulator was created for assisting in enhancing the quality of the Information Assurance courses offered to cadets of the US Military Academy. At a certain moment [9], MAADNET designers decided to take the option of collaborating and improve the work already completed by the creators of CyberProtect (see section A above). MAADNET was adopted by the US Defense Information Systems Agency (DISA) as an education tool for user, manager, and technician education.

The tool has been built using an Object Oriented Design with Java applets. It was also foreseen to be utilized as a web based application using Java Web Start technology. The server hosts the simulation engine, the attack scenarios and the evaluation mechanisms. On the other hand, the client hosts a scenario generator tool, a network builder and the simulation viewer. The simulation offered is a high-level one not providing all the details down to the network protocol level. The network is built using different components such as switches, routers, workstations, wireless access points, etc. Each of these components can have one or more traffic generators associated to it.

In order to generate realistic events, the Mean Time Between Failures (MTBF) is one of the parameters that could be configured for each of the entities. Also, the Mean Time To Repair (MTTR) is another parameter that can control the time that takes to put again the component into an operational status.

The defense strategy is static: once that the network has been built, it will not change during the simulation of the selected scenario. On the contrary, the attacks are dynamic in nature based on the specific scenario. The probability of an attack succeeding is a function of the type of attack and the skills of the attacker. Creating reliable and credible attack/defense models of an acceptable quality is the main challenge here. Attack trees and Petri nets have been used to model and represent the attacks within MAADNET. The modeled attacks can be from the Internet (outsiders), from an authenticated user (insiders) or from the wireless infrastructure (both outsiders and insiders).

*C. **CyberOps: NetWarrior**, developed from the above one by US DoD's Defense Information Systems Agency (DISA) [10].*

CyberOps: NetWarrior has been developed from the "Military Academy Attack/Defense Network (MAADNET)" simulation closing the evolution of the product line presented in the two previous sections. The main enhancements introduced are related to the improvement of the interactivity and a web based approach with better graphics.

The tool is an immersive 3D virtual environment, with realistic looking network equipment, similar to an interactive video-game, where the player (student) has to create a network within specific resource constraints. The student selects the security defensive tools and other options that are going to be used on his/her network and then sequences of computer generated attacks are launched in order to assess the strength or the selected solution.

The evaluation performed by the tool takes into account parameters such as the utilization of specific security hardware and software, the policies and procedures in place, and the impact due to the (un)availability of the specialized information assurance virtual personnel, as well as their training, certifications and experience. Money is limited so the student needs to perform a cost/benefit analysis in order to make right choices when building the network. The students receive feedback that helps them to understand their success or failure in protecting the network. This feedback is dynamic and it is only related to the specific configuration selected by the student.

CyberOps can be used as academic classroom, technical training and computer network defense exercise support tool through a series of security roles such as NetBuilder, NetDefenser, NetAssurer and NetWarrior. Multi-player game has been enabled and students can group in Blue (defenders), Red (attackers) and White (referees) teams in an interconnected exercise.

*D. The cyber DEfense Technology Experimental Research laboratory (**DETERlab**) of the Information Sciences Institute of the University of Southern California [11].*

The DETERlab testbed uses the Emulab cluster testbed software developed by the University of Utah. It is a public facility whose utilization for information security research purposes can be requested by any principal investigator to the Emulab Approval Committee. Using DETERlab, a pool of experimental nodes can be controlled and interconnected in nearly-arbitrary network topologies.

The DETER testbed facility, from its inception in 2004, has not been aimed to be used for teaching objectives for users without a solid background in information assurance but for researches made by a relatively small experimental community. It could be anyway used for educational purposes provided that the target audience has the necessary level of knowledge. The DETERlab testbed has been used as a laboratory by university-level cyber-security classes.

DETERlab possess a model for dynamic federation that enables separate testbed facilities to come together on demand in order to support large-scale, complex, heterogeneous, multi-party experiments. In order to support such complex experiments, a tool has been developed for provide the researchers with the possibility of easily creating, planning and iterating through a large range of experimental scenarios: SEER (Security Experimentation EnviRonment) [12]. SEER comprises several tools for the configuration and execution of experiments and provides a user-friendly interface for the investigators. Some of those tools included in SEER are traffic generation tools, attack tools, network configuration tools, and data collection and presentation tools.

The main DETER aim is to be able to provide support for security experiments that are repeatable. This enables the researcher to repeat the experimental conditions accurately and to modify them only in a controlled manner. Currently the testbed is composed of two linked clusters: one at USC ISI and the other one at UC Berkeley, with around 300 experimental nodes at the moment of writing this article.

*E. **CyberCIEGE** from the Center for Information Systems Security Studies and Research of the US Naval Postgraduate School [13].*

CyberCIEGE is a high-end, commercial-quality video game developed jointly by Rivermind and the Naval Postgraduate School's Center for Information Systems Security Studies and Research [14]. The tool shows a simulation in which the student has to be the decision maker of an IT organization. The aim of the game is to protect the system by using appropriate security measures involving procedures, physical and technical security, while keeping the virtual users productive and pleased.

The number of different scenarios that can be played is unlimited since CyberCIEGE has been designed to be completely extensible. Apart from the simulation engine itself, CyberCIEGE includes a scenario definition language (with the corresponding definition tool - SDT) and a scenario development tool that enable creating completely new situations, and a context-sensitive video encyclopedia that serves as instructional aide.

Some of those new scenarios have also been developed within the Center for Information Systems Security Studies and can be obtained from [15].

CyberCIEGE is available at no cost to agencies of the US Government and there are also educational licenses available at no cost to educational institutions. Finally, there is a free evaluation version that has limited capabilities.

A comparison between the features offered by CyberCIEGE and the ones by CyberOps NetWarrior (see section C above) can be found at [16]

*F. NIST IPSec and IKE Simulation Tool (**NIIST**) [17, 18].*

NIIST is an integrated Internet security simulation framework developed by the National Institute of Standards and Technology (NIST). The tool has been implemented in Java and integrated in the Scalable Simulation Framework (SSF), a discrete, event-driven, scalable modeling framework, and SSF Network Model (SSFNet) [19], a collection of Internet modeling tools for simulating Internet protocols and networks. SSF is mainly focused in scalability and high-performance for large networks simulation.

While the main goal of NIIST is not to serve for the security education or training, but to characterize and study IPSec/IKE performance and its influence on end-to-end protocols such as TCP, it still could be used to teach the fundamentals of the Virtual Private Networks (VPNs) and IPSec.

*G. The Real-time Immersive Network Simulation Environment (**RINSE**) for Network Security Exercises of the Information Trust Institute of the University of Illinois at Urbana-Champaign [20].*

RINSE is a highly extensible simulator designed for large-scale, real-time cyber-security training and exercises. The simulator consists of five components: the iSSFNet network simulator, the Simulator Database Manager, a database, the Database Server, and client-side Network Viewers. The iSSFNet network simulator, which was previously known as DaSSFNet, is the latest implementation of the C++ network simulator based on the Scalable Simulation Framework (SSF) [19] mentioned and referenced in the previous section.

Every simulation entity connects to the Simulator Database Manager, which provides the data from the simulator to the database and delivers control information from the database to the simulator. The Database Server communicates with client applications, such as the Java-based application “Network Viewer”, which allows the users to monitor and control the simulated network from the client side. From there, the user can issue several commands in order to influence the model behavior. These commands include five different types: attacks, defenses, diagnostics networking tools, device control, and simulator data.

As other simulators presented in the article, the type of educational target for this tool is aimed at large-scale network exercises. However, it still can be used for smaller security training scenarios in order to teach specific information assurance issues on a network.

RINSE has evolved into a more complex and generic network simulator: PRIME (Parallel Real-time Immersive network Modeling Environment) for large-scale real-time network simulation [21]. PRIME is a project of the Modeling and Networking Systems Research Group within the School of Computing and Information Science of the Florida International University that has also been used for information security studies such as attacks in routing environments [22].

*H. The Reconfigurable Cyber-Exercise Laboratory (**RCEL**) for Information Assurance Education at the Center for Information Systems Security Studies and Research of the US Naval Postgraduate School [23].*

RCEL is the result of a Master’s Thesis developed by R. J. Guild within the US Naval Postgraduate School in 2004. The thesis describes the laboratory as a “flexible collection of equipment that can be quickly interconnected and configured” [23] and illustrates six practical scenarios with different learning objectives. These scenarios provide the students with the opportunity of participating in all phases of the security lifecycle: analysis, design, construction and operation. The lab configuration can be quickly changed in order to be used for different activities. In this case, the author proposes the use of Symantec Ghost to create images of pre-configured stations that could then be rapidly deployed when required.

The lab is composed of several stations each of which are specialized in one network function, such as: authentication, domain controllers, DNS server, DHCP server, FTP server, PKI Certification and Registration Authorities, syslog server, e-mail server, web server, database server, disk images storage server, wireless access points, honeynet, vulnerability assessment (VA), switches, routers, firewall, Intrusion Detection System (IDS) and Virtual Private Network (VPN) devices. One lab can be interconnected to another remote one using a public network by means of a VPN. Whether interconnected to another remote lab or not, the main idea for each learning exercise is that part of the LAN (or a complete VLAN) is acting as attacker while other parts act as defenders.

Probably virtualization, while existing, was not so widely spread when this thesis was written. If we would like to build a similar laboratory today we would most likely use virtualization instead of having dedicated specialized stations for each of the network functions. The maturity of virtualization and the processing power of current hardware allow doing so with an acceptable performance as we can see in the system presented in the following section.

*I. **Tele-Lab “IT Security”** from the Hasso-Plattner-Institut für Softwaresystemtechnik GmbH at Postdam, Germany [24].*

Tele-Lab “IT Security” is a web-based tutoring system that introduces students to fundamental IT security concepts and provides an on-line virtual laboratory for them to be able to gain practical experience.

The system leverages virtual machine technology for using a single host system as many different machines at the same time and to assign a remote machine to a student providing him/her with administrator rights without jeopardizing the stability and security of the training system.

Tele-Lab is implemented by using User-Mode Linux. Users manage the virtual machines by means of a connection that uses the Virtual Network Computing (VNC) client application.

*J. The Network Security Simulator (**NeSSi2**) developed at the DAI Laboratory, part of the School of Electrical Engineering and Computer Science of the Berlin Institute of Technology, and sponsored by Deutsche Telekom Laboratories [25, 26, 27].*

NeSSi2 is an open source discrete event network simulator, published under the Apache 2.0 license, incorporating several security-related capabilities that makes it different from the general purpose simulators, such as profile-based automated attack generation, traffic analysis and interface support for the plug-in of detection algorithms. The plug-in concept allows the functionality extension without changing the simulation core itself. Theses extension mechanisms allow three different levels of abstraction: application, network and device level.

NeSSi2 is built on the JIAC framework [28], a service oriented architecture based on agents. Agents are used in NeSSi2 for modeling and implementing the network devices such as routers, clients, and servers. JIAC agent framework provides a rich and flexible basis for the implementation and testing of diverse security configurations and algorithms in NeSSi2 that allows combining the partial knowledge of the agents residing in the network, in a cooperative approach for identifying and eventually eliminating IP-based threats.

NeSSi2 consists of a simulation back-end, a front-end (Graphical User Interface – GUI) and a database management system hosting the results database. The back-end and the frontend are available for download, for Windows, Linux and Mac OS, at NeSSi2 website [26]. For the database management system, NeSSi2 developers recommend MySQL but SQLite is also supported. The simulator has been built using Java SE 6. The subnets, the network elements and their properties, have been modeled using the Eclipse Modeling Framework (EMF) [29] which also enables automated source code generation and, thus, the model can easily be extended.

K. ***S-vLab**, an experimental environment for teaching Java security developed at the University of Bologna, Italy [30, 31].*

S-vLab is a virtual laboratory for supporting teaching and learning in different domains. Among them, S-vLab can also be applied to the information security area, being one of its main goals helping students in understanding the Java Security Platform.

The tool provides a graphical editor and a set of building blocks that are suitable for designing a simplified version of a system or protocol. In order to test and assess the efficacy and the strength of the proposed solution, students are able to simulate attacks. When playing the attacker role, students improve their knowledge on how to analyze systems for weak points, how to choose designs that prevent these flaws, and how to deploy defenses.

*L. A Windows Attack intRusion Emulator (**AWARE**) from Fairmont State University [32].*

AWARE is an emulator built on Microsoft Windows XP and for Windows XP users. Its main aim is teaching those users to detect potential attacks using the XP included tools and to remediate the effects of those attacks. Some of the XP emulated tools include: the Process List inside the Task Manager, the Registry Editor (regedit), a visual version of netstat (in order to search for unusual port traffic) and a limited version of the Windows Firewall log.

The system also includes built-in tutorials that help the user in understanding the tools, how to use them, how they look like, etc. At the end of the simulation, the user is presented with an evaluation of the results obtained with an indication on how well he/she did.

The emulator tries to change users' passives attitudes and to provide them with the possibility of counteracting future attacks. Previous computer security knowledge is not required.

M. ***RADICL**: A Reconfigurable Attack-Defend Instructional Computing Laboratory from the Department of Computer Science of the University of Idaho [33].*

RADICL is a highly reconfigurable laboratory which main objective is to enable students to understand attack scripts and other malware and to use defensive strategies and tools. It has been designed and developed by senior and graduate students in Computer Science, Computer Engineering, and Mathematics.

The requirements include switching operating systems on each laboratory machine and reconfiguring the network topology in less than four minutes. In twelve minutes, starting from machines without partitions and without operating systems installed, RADICL can be completely configured and ready to run.

The laboratory comprises sixteen workstations with dual NICs and one Xeon server that hosts the OS images. Each of the workstations is partitioned into nineteen segments with the same size in order to provide multi-OS booting. The different networks are separated by using VLANs. Most RADICL activity does not require advanced networking. A KVM switch allows the control of any of the seventeen machines in the laboratory. The central image server consolidates all RADICL capabilities into a single web-based front end making unnecessary moving hardware or unplugging and plugging cables and devices.

Further development has been made in order to extend the capabilities of the original RADICL lab. For example, Team 54 of the Computer Science Department of the University of Idaho has extended the project and renamed it as Vrad LAB [34]. Among other improvements we can find the use of virtualization by means of VMware which enables the possibility of running up to 16 virtual machines concurrently, the central storage of operating system images on a server, the possibility of running multiple isolated experiments and the remote access to the lab.

Not all the analyzed tools are easily accessible; therefore not all of them could be tested, as it was the authors' intention. It appears that it would be a good idea to have more open source, freeware and/or inexpensive developments in this area and specifically individual tools that allow easily good performance training. Within the Electrical and Computer Department of the Industrial Engineering School of UNED (Spanish University for Distance Education) there are several efforts in order to provide such tools not only for the students but also for the general public.

One of those applications is the information security didactical system presented at [35] that comprises two different tools: a network attack simulator and an intrusion detection system, IDS. Both tools share a usable and really friendly interface, and are distributed as a kit that can be easily installed by the student in any computer, since the system is open-source and multi-platform. The system has been developed in Java using Eclipse IDE. The system allows two types of users: the student that wants to explore more in detail the way an IDS works, and the collaborator who would like to extend the system by adding new features, such as new attacks and new signature attacks for the IDS.

Another example is fragSim [36], an interactive simulator for studying the IP fragmentation process that is in the process of being extended to include extra functionality. fragSim is a completely web based network simulator developed for the Adobe Flash framework. This makes possible to have access to the simulator from almost any imaginable platform with the only pre-requisites of being connected to the Internet and having a web browser with the Adobe Flash plug-in installed. The simulator allows a degree of user interactivity where the user is able to define the desired network topology, the value for the Maximum Transmission Unit (MTU) on each of the links and the size for the telecommunications protocol stack upper layer messages that will be fragmented. The application has also been built to be graphically attractive in order to positively influence the user learning experience while capturing user attention. fragSim has been in use during the academic year 2008/2009 by the students of two subjects within the Industrial Engineering School of UNED (Spanish University for Distance Education): "Industrial Communications" at 5th course of the MSc in Industrial Engineering, and "Industrial Communications Networks" at 3rd course of the BSc in Industrial Engineering. Unfortunately, it is still soon to have enough student evaluations in order to assess their perception when using fragSim, but the tool will continue to be available to the same students on following academic years and it is planned to expand the usage to other computer network and communications courses. It is expected to receive valuable feedback that allows the implementation of improvements and new features.

III. TAXONOMY

Saunders [1, 2] produces a taxonomy by classifying the information security simulators in five distinct categories: PacketWars, Sniffers + network design tools (also named Flexible Network Design in other parts of his document), Canned attack/defend scenarios, Management flight simulators, and Role-playing.

PacketWars refers to a type of simulation that utilizes network attack and defense at a tactical level. Most of the simulators in this category are implemented in real networks with real equipment but not necessarily all of them due to the benefits of simulation and/or virtualization. The network infrastructure used to organize annual Cyber Defense Exercises (CDX) by governmental/military authorities, such as the ones organized by the US National Security Agency (NSA) [37] or the North Atlantic Treaty Organization (NATO) [38], will also fall into this category.

Sniffers + network design tools category comprises the tools that combine the use of Network Modeling and Simulation (NMS) packages with the use of network protocol analyzers (also known as sniffers). In this category, the tools mentioned in the introduction of section 2 [3-6], would be included. In this article, we have also included tools that work as a generic NMS but are specialized in information security modeling.

Canned attack/defend scenarios includes most of the tools analyzed in this article. According to Saunders, here we refer to simulators that are typically standalone and can be used as a game. As we have seen in the previous section, some of them have evolved incorporating the possibility of connecting to other remote "players" or being remotely managed. Therefore, not all of them are completely standalone applications.

Management flight simulators are, according to Saunders, applications built using a System Dynamics or a Discrete Event Simulation (DES) tool. However, in the research, we have not considered the requirement in this statement to be essential and, following [1, 2], the key feature considered for including one of the simulators in this category is the management of resources (money, personnel, devices, etc.) during the simulation, regardless of the tool used to develop the system or its use only by managers or directors.

Role-playing is a type of simulation that does not employ computer-based simulations but, as it can be easily inferred, actors playing different roles within a given scenario. In this area, the Cyber Defense Exercises mentioned before, in their part related to the strategic level decisions, would be included.

Taking into account these descriptions, the simulators analyzed in this article have been classified in Table I:

TABLE I. CLASSIFICATION UNDER SAUNDERS CATEGORIES

Simulator Name	Category
CyberProtect	Canned Attack/Defend Scenarios
MAADNET	PacketWars
CyberOps: NetWarrior	Canned Attack/Defend Scenarios
DETERlab	PacketWars
CyberCIEGE	Management Flight Simulators
NIIST	Not applicable
RINSE	PacketWars
RCEL	PacketWars
Tele-Lab "IT Security"	PacketWars
NeSSi2	Sniffers + Network Design Tools
S-vLab	PacketWars
AWARE	PacketWars
RADICL	PacketWars

As Table I shows, most of the tools analyzed in this article fall under PacketWars category. Saunders' classification was done with the aim of assisting in making a decision about the level of effort that would be needed to get started in the information security simulation world. However, the presented categories do not provide per se the intended knowledge to serve as assistance for making a decision; nevertheless, the required knowledge can be inferred from [1, 2], specially from the categories comparison table included there.

Therefore, in this article, the taxonomy has been broken down into several distinct tables. On the first two (tables II and III), the general technical features of the analyzed tools will be presented while, on the other two (tables IV and V) the focus will be put on the features related to the teaching and didactical capabilities of the tools.

TABLE II. TECHNICAL FEATURES

Simulator Name	Type	Remotely usable	Virtualization
CyberProtect	Simulator	No	No
MAADNET	Simulator	Client/Server Architecture	No
CyberOps: NetWarrior	Simulator	No	No
DETERlab	Laboratory	Yes (using a XMLRPC API)	Yes
CyberCIEGE	Simulator	No	No
NIIST	Simulator	No	No
RINSE	Simulator	It can be interconnected to real-world networks	No
RCEL	Laboratory	It can be connected to external organizations by means of a VPN	No
Tele-Lab "IT Security"	Laboratory	Yes	Yes
NeSSi2	Simulator	Yes (installing the frontend on a different machine)	No
S-vLab	Laboratory	Yes	Yes
AWARE	Emulator on Windows XP	No	No
RADICL	Laboratory	Web interface configuration	Yes

Type indicates the type of analyzed tool. Most of them are simulators, some of them are laboratories and we have an instance of an emulator.

The second column indicates if the tools can be remotely managed/operated.

The third column shows the virtualization capabilities of the tools.

Table II shows how analyzed tools have been classified into three types. Many of them are simulators: computer applications that reproduce the system behavior under certain specific conditions. One of them could be classified as an emulator: a computer application that models a system accurately, mimicking its actions and trying to exactly match the same behavior as the real system. The third type is for computer laboratories: sets of real devices typically separated from the production networks, and which main objective is to perform experiments in a controlled environment.

Regarding the capability of being remotely used, we have found tools that can be managed via web, by means of a custom made client/front-end, using an Application Programming Interface (API), and even connecting to real-world networks, or the ones that do not have any of these possibilities.

Finally, in table II we have classified the tools by indicating which ones use virtualization and which ones not. Virtualization is a technique that allows partitioning a single physical machine into several virtual machines that typically can run different instances of the operating system, not being necessary that those instances are identical or even of the same operating system.

TABLE III. TECHNICAL FEATURES (CONTINUED)

Simulator Name	Standalone	Scalability	License
CyberProtect	Yes	Limited by HW features	Unclassified application available at no cost
MAADNET	No	Limited by HW features	Not available outside USMA
CyberOps: NetWarrior	Yes	Good (by means of new scenarios)	Unclassified application available at no cost
DETERlab	No	Excellent (DETER Federation)	Public use. Projects under a principal investigator previously authorized by Emulab Approval Committee
CyberCIEGE	Yes	Good (by means of new scenarios)	Commercial. No cost for US Government or Education Institutions (also outside US). Free evaluation coy available
NIIST	Yes	Not applicable	Open Source
RINSE	No	Excellent	Open Source (PRIME SSF and PRIME SSFNet)
RCEL	No	Fair (by adding more machines or by interconnecting with other labs)	Not available outside NPS
Tele-Lab "IT Security"	No	Very good	Open Source
NeSSi2	Yes	Excellent	Open Source
S-vLab	No	Unclear	Open Source
AWARE	Yes	Not applicable	Unknown
RADICL	Yes (the network lab is not connected to other networks)	Fair (by adding more machines)	Available only at the University of Idaho

Standalone indicates whether the analyzed tool is/can be installed on a single machine.

The second column gives an indication of the growing capacity of the tool.

The third column expresses the type of license under which is distributed the tool.

In Table III, the tools have been classified as standalone or not. A standalone application is one that can run without a network connection on a single system. Please note that RADICL has been classified as standalone but taking into account that the whole laboratory itself is not connected to networks other than its internal one.

On the second column, a classification measuring the level of scalability of the solution has been presented. The scalability is the property that allows expressing the growing ability of the tool both in terms of handling increasing amounts of tasks and in terms of being readily enlarged. A scale with values: poor, fair, good, very good and excellent has been used.

The last column on this table indicates the type of license used for the tool distribution, if any. Note that some of the laboratories (MAADNET, RCEL and RADICL) can only be used on the premises where the lab is installed since they also do not have the possibility of being remotely managed.

There are not many tools that are ready to be used for standalone study. This is of paramount importance for the typical student of an Open University. Further development on such tools and/or simulators in-the-cloud would be desirable.

Also, while we found some tools that are open source, for public use or at no cost for educational institutions, it would be worthy to count on further efforts on this area.

Finally, it is necessary to remark that all of the tools found are in English, while it was expected finding some tools completely translated into other widely spread languages, such as Spanish. S-vLab web site and documentation is in Italian.

TABLE IV. DIDACTICAL CAPABILITIES

Simulator Name	Target Audience	Teaching Objectives	Learning Curve
CyberProtect	Novice network security professionals	Generic information security training	Fast
MAADNET	US Military Academy cadets	Generic information security training	Fast
CyberOps: NetWarrior	Information Assurance Students	Generic information security training	Fast
DETERlab	Academic and industrial cybersecurity researchers	Teaching is not the main target. It has been used as a laboratory by university-level cyber-security classes	Slow
CyberCIEGE	Information Assurance Students	Information assurance basics. Risk management. Resource management	Fast
NIIST	Researchers of new and existing intenet security technologies, protocols or protocol mechanisms	Research and evaluate the dynamic behavior of an interacting suite of security protocols in large scale VPNs	Slow
RINSE	Experienced network security professionals	Large-scale, real-time cyber-security training and exercises	Unclear
RCEL	Information Assurance Students with a profound technical background	Support of an information assurance education program	Moderate
Tele-Lab "IT Security"	Information Assurance Students with minimum previous knowledge	Many different subjects. Basic level	Moderate
NeSSi2	Computer Science students and professionals	Detailed examination and testing of security-related network algorithms, detection units and frameworks	Moderate
S-vLab	Students of 4º course in a 5 years degree	Java Security	Fast
AWARE	Windows XP users	Detect potential attacks and remediate the effects using Windows XP built-in tools	Fast
RADICL	Information Assurance and Computer Engineering Students	Understanding attack scripts and other malware	Moderate

The target audience column shows the expected main “customers” for the tool.

The second column provides a description of the main topics that the tool could be demonstrating to a potential student.

The third column depicts the speed of the learning process from the moment that the tool starts to be used.

In Table IV, as target audience we have mainly found information assurance students within computer science courses/degrees. However, the complexity of the tools makes some of them unreachable for people without a solid background in networking and information security. It is remarkable that there is one tool (AWARE) that is clearly targeted to users with only a basic knowledge on using their personal computers. The authors have tried to obtain the tool from the developers for further assessment without response so far.

The learning objectives cover a wide range of completely different possibilities. While some tools’ aims are deliberately high-level, specific ones, due to their focus on large-scale, complex experiments, many of the analyzed tools show different levels of generic information security training even appropriate to novice students. Those complex ones are not suitable for being used as starting point for teaching information security.

At learning curve column, an indication on the level of effort required for the student to be able to use the tool at an acceptable level of efficiency is shown. The use of the term “steep” has been intentionally avoided since sometimes has different interpretations. The used values are: slow, moderate and fast, being “slow” the one that shows more difficulties in reaching the target and “fast” the one with fewer difficulties.

TABLE V. DIDACTICAL CAPABILITIES (CONTINUED)

Simulator Name	Usability	Level of Detail
CyberProtect	Very good	Fair
MAADNET	Very good	Fair
CyberOps: NetWarrior	Excellent	Good
DETERlab	Good	Excellent
CyberCIEGE	Excellent	Good
NIIST	Fair	Very good
RINSE	Good	Good
RCEL	Good	Excellent
Tele-Lab "IT Security"	Good	Unclear
NeSSi2	Very good	Excellent
S-vLab	Good	Fair
AWARE	Very good	Fair
RADICL	Good	Very good

The usability denotes the ease with which the students can employ the analyzed tools in order to achieve the learning targets.

The second column shows how complex is the tool and how accurately represents the real system.

Finally Table V shows, for the usability, the values poor, fair, good, very good and excellent have been chosen, being “poor” the value that express a condition in which the student hardly can utilize the tool for achieving the objective without a considerable effort, and “excellent” the situation where the student start receiving benefits from the learning action from the very beginning.

The level of detail is related to the didactical capacity since it indicates the fidelity of the abstraction that the tool provides. It has to be noted that the closer to the real system, the higher the level of detail, but also the bigger the effort required. The values are exactly the same as the ones in the previous paragraph with a similar meaning.

As a final point, it can be added that it would be desirable to have more tools for students without previous experience in information assurance issues and covering diverse related aspects.

CONCLUSION

Not all the security simulators found and analyzed in this article are mainly developed having information security education, training and/or awareness in mind. However, most of them can be used in the purpose of illustrating different information assurance concepts and ideas. It would be desirable, anyway, that new tools were developed with a focus on enabling information assurance concepts teaching, not only for university students but also for anyone interested professionally in these subject matters. We think also that these tools must be extremely easy to use and also individualized, allowing a deep understanding of the concepts by doing “experiments” in the students’ own environment. In that sense, we are developing an effort to create an integrated toolset of information security training tools, in order to illustrate different aspects of the subject matter and we are also evaluating which of the analyzed tools in this paper could be part of this toolset.

When the tools research was started it was expected not to find many. Even when the number of identified efforts is non negligible, it can be stated that there is still a long way to be followed until finding an acceptable diversity in this kind of tools covering every information assurance aspect that needs to be taught. Therefore, further developments in this area are going to be, for sure, warmly welcomed by the education community.

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Session 11E ANECA Special Session: New Directions in Engineering Accreditation, Quality and Course Design

New Directions in Engineering Accreditation
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Course design approaches for the EHEA. Scaling up from pilots.
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Directions in Quality
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New Directions in Engineering Accreditation

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Recent decades have seen internationalization of the engineering practices thus making engineering education an international enterprise. Graduates from a certain engineering program may have to work not only in a different state (in case of USA) or a different country. The graduate may also be working in a multinational company. This situation further increases the interest among the institutes to get their program accredited. An accredited degree program is the one that has gone through a rigorous quality control system and has been approved by a national or international accrediting agency or organization. The importance of graduating from such programs is growing with the increasing demand of global engineers.

Engineering educators need to focus on several key areas, among which are development of curricula, graduate studies, research, development and promoting university-industry ties, and accreditation. Accreditation provides an educational institution or a program with a credential. The credential is most often a public statement that the academic unit satisfies a set of quality criteria established by the accrediting body. Through the accreditation process, the faculty, the facilities, the student body, budgets, recruiting practices, admissions procedures, course content, and other pertinent issues come under thorough review. The accreditation process may operate at a broad or narrow scope. A panel discussion is organized to discuss new directions in engineering accreditation. EDUCON-2010 panel session will provide a unique opportunity to educators, researchers and technologists who are willing to discuss how they are integrating digital technologies, instruction, and changes to university facilities in their programs seeking accreditation or how they think it should be done. It will also provide a forum for discussing and debating new directions and approaches relevant to accreditation with eager industrial and academic audiences. Following are some of the relevant questions that we would like to address during this panel session;

- Does accreditation help to maintain quality of education?
- What is the impact of accreditation on traditional learning environment?
- Are traditional approaches to accreditation meeting today's need?
- What are some of the problems with accreditation?
- How can accreditation be reformed?
- What are the new trends in accreditation?
- What are the important issues specific to engineering accreditation?
- What incentives do faculty members need in order to commit to accreditation activities?
- What are the alternates to accreditation, if any?

All these questions are the subject of ongoing attention and discussion by academicians, ABET and in various ways by other ABET member scociteies.

Course design approaches for the EHEA

Scaling up from pilots

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Abstract— **After years of preparation and limited-scale pilot projects, full blown implementation of European Higher Education Area (EHEA) compliant degrees started in 2008 at the UC3M. This paper discusses the final stages of preparation, as well as the initial lessons from this go-live experience, focusing on a core (compulsory) second year subject of the computer engineering curriculum whose full-scale implementation started in 2009. Lessons drawn from the preparatory pilots are presented, implementation challenges are identified and analyzed, and both school-level and course-level required design approaches are discussed. Conclusions highlight that successful adoption of some critical elements of the EHEA methodology in the Spanish engineering education environment is far from certain.**

Keywords- Bologna, EHEA, course design, curriculum development

I. Introduction. EHEA adoption in Spain

The 1999 Bologna Declaration, currently endorsed by 46 countries, aims at the creation of a European Higher Education Area (EHEA) based on international cooperation and academic exchange [1]. It involves major reforms in the higher education systems (as well as an alignment processes with the European Research Area), including: Common adoption of a three-cycle structure (e.g. bachelor-master-doctorate); Quality assurance in accordance with the Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG); Fair recognition of foreign degrees and other higher education qualifications in accordance with the Council of Europe/UNESCO Recognition Convention.

In Spain, the first EHEA-compliant bachelor degrees started in September 2008, among substantial controversy. 33 Spanish public and private universities, out of the 75 existing ones, offered 163 programs. By Sept 2010, all bachelor degrees must be EHEA-compliant.

The Bologna Process Stocktaking Report 2009 [2] analyzes and compares, using various criteria, the current implementation status of participating countries, and Europe as a whole. More specifically, the Spanish National Report compiled by the Spanish Government in 2009 discusses in detail the current status of EHEA adoption in Spain [3].

The Spanish National Report analyzes the evolving regulatory framework within which EHEA implementation in Spain is taking place. This framework encompasses Royal Decree 56/2005 of 21st January, on official postgraduate studies. This Decree, later superseded, created a temporary legal base which led to the first EHEA-compliant postgraduate degrees, even though no EHEA-compliant undergraduate degrees (the natural source for candidates) could still be offered. The current regulatory framework is largely determined by Royal Decree 1393/2007 of 29th October, which regulates the organization of official university education and develops the new structure, encompassing:

- First cycle (Bachelor). According to EHEA agreements it could range between 180 and 240 ECTS; in Spain it has been standardized at 240 ECTS credits, equivalent to 4 years of full time study.
- Second cycle (Master's) studies, ranging from 60 to 120 ECTS credits.
- Third cycle (Doctoral) studies lasting between 3 and 4 years.

Royal Decree 1393/2007 defines 5 broad "branches" for undergraduate degrees: Arts and Humanities, Natural Sciences, Social Sciences and Law, Health Sciences, and Engineering/Architecture. Each undergraduate degree must be ascribed to one of these branches and must include at least 60 ECTS of "basic" courses. At least 36 ECTS of these "basic" courses should be on the topics listed for the degree's branch. For example, any Engineering/Architecture degree should include at least 36 ECTS credits from physics, mathematics, computer science, business administration, graphical expression (i.e. technical drawing), and chemistry [4]. No content guidelines were specified for master's level degrees in order to encourage universities to foster their unique specializations. Special degrees such as Medicine should be regulated separately from other degrees. Those degrees requiring certification for professional licenses such as engineering require additional content guidelines; however, these additional guidelines were not prescribed in R.D. 1393/2007; for engineering degrees, were only issued in February 2009, as discussed below.

Royal Decree 1393/2007 also replaced the previous government-approved closed catalogue of official engineering degrees by an open-ended evaluation and accreditation process whereby each university could propose whichever bachelor degrees it deemed appropriate. Therefore, these 163 new degrees were, for the first time, designed without a government-provided template.

II. CURRICULA DESIGN AND APPROVAL

The public university Carlos III of Madrid (UC3M) was the only one to embrace a big-bang conversion approach, proposing a simultaneous replacement of all its existing engineering degrees by the new ones. After completing the Quality Assurance review (ANECA), 80% of these proposals were approved by the education authorities, thus, in September 2008, 8 out of its 10 undergraduate engineering degrees were discontinued, and replaced by new offerings conforming to the new cycle structure, credit transfer system and pedagogical and assessment approach. The two remaining ones, which were particularly affected by unsettled elements of the regulatory environment (specifically, professional licenses granted at the master's level) will be transformed in September 2010.

This meant that all UC3M engineering degrees were simultaneously redesigned. Furthermore, as previously discussed, the curricula for these degrees were, for the first time, designed without a government-provided template, subject solely (since they all belonged to the Engineering/Architecture branch) to the stated prerequisites on the 60 ECTS of "basic" courses, encompassing 36 ECTS credits from "basic" subjects.

This created an opportunity to exploit synergies between degrees [5]. In some cases, such as the Univ. Europea de Madrid's Health School, the gradual (and, therefore, only partial) conversion to EHEA of related degrees has delayed the materialization of these synergies, while on the other hand it has provided the opportunity to gain from the experience of the first ones to undertake a full conversion (e.g., better understanding of the potential of IT support tools, such as anti-plagiarism tools). In the school of engineering of the Carlos III University, the first two years of degrees belonging to the same "family" (industrial, telecom, computer science...) will be identical, to allow for built-in flexibility for late career path changes as well as resource pooling in areas such bilingual groups. Furthermore, the February 09 decrees, that established additional content guidelines for regulated engineering professions requiring professional licenses, imposed "family modules" (i.e., "Módulos comunes a la rama industrial"), that all degrees of the same family must include in their curricula, in addition to the basic branch-linked subjects. Since these additional guidelines were issued when the corresponding bachelor degrees were already being offered at the UC3M, some "retro-fitting" has been performed on the curricula – and sent back to the education authorities for approval - to ensure they conform to the guidelines.

Implementing these changes while the degrees are already being taught complicates the process further. At UC3M, complying with the guidelines has often merely required minor content changes in various course descriptions, but in a few cases it has forced to introduce new courses (and delete others). Since the new degrees started in September 2008, and the new guidelines were published in February 2009, these changes are being located in the curriculum, whenever possible, not earlier than the second quarter of the second year, so that the first cohort of students had not taken these courses yet. As an example, the subject discussed in this paper, Foundations of Engineering Management (FEM), had to be moved, in three degrees, from 4^{th} year to 2^{nd} year. In some of these, it might have been preferable to locate it in the first term. However, since students would be attending the first term of the second year by the time the proposal would be approved, they were all assigned to the second term.

This issue is also complicated by the coexistence of professional licenses that require a bachelor degree and others that require a master degree. As an example, a bachelor in electrical engineering will be entitled to sign electrical projects. A bachelor in mechanical engineering will be entitled to sign mechanical projects. However, if either of them goes on to complete a masters program in industrial engineering, he/she will be entitled to sign both electrical and mechanical projects.

These changes also led to the creation of some subjects, corresponding to the list of the Engineering/ Architecture basic topics, which spanned all the engineering degrees. The subject analyzed in this paper, Foundations of Engineering Management, implements the "business administration" basic topic, and spans 7 different engineering degrees, from Telecommunications to Mechanical Engineering.

Regarding methodology, the Bologna process was supposed to involve a significant shift from instructor-centered "teaching" to student-centered "active learning". This necessitates methodological changes such as implementing continuous evaluation schemes, de-emphasizing theory-only lectures, developing assignments and class projects, and encouraging hands-on experiences. It should also allow the students to design their own curricula with a higher level of flexibility.

III. PREPARATORY PILOTS. LESSONS DRAWN

In preparation for the full-scale implementation, the UC3M and specifically its School of Engineering has been experimenting, learning and paving the way for these pedagogical changes while the legal framework was being finalized. Some groups were created for testing purposes and some degrees were chosen to extensively test out the new methodologies. The UC3M has funded a number of methodology adaptation projects and faculty training. New metrics for evaluating the faculty performance and a support infrastructure for the new pedagogical approaches have been developed. New computer tools, deemed more appropriate for the new environment, were sourced and tested (Moodle-based LMS, Turnitin© ...).

In anticipation of this full-scale implementation, the group involved in the project presented in this paper has gradually introduced, in the last few years, various elements of the methodology in lower-volume courses in existing degrees, and various approaches have been tried and evaluated in terms of their effectiveness and their scalability.

The EHEA-compliant Master in Engineering Management and Logistics, established under the provisions of Royal Decree 56/2005 and coordinated by one of the authors, has become an integrated testbed. Since its inception in 2006, all its subjects have been taught following the Bologna approach: approx. 50% of the grade is based on continuous evaluation, attendance is compulsory, emphasis has been shifted from lectures and theoretical examinations to individual and group assignments, number of lecture hours per ECTS has been reduced while workload has been concentrated in the student preparation, etc. This has provided valuable insights into the potential learning effectiveness of these approaches, but has also highlighted its difficulties and the risk of the instructor's workload exploding out of control, particularly in terms of grading assignments. Care must be exercised, however, while extrapolating these experiences to undergraduate courses, since Master students have a different, more mature profile and their number has been capped at 20.

To get some insights from student groups that are more similar to the undergraduate courses in which EHEA is initially being fully implemented, partial pilots have also been carried out in various student groups of the existing undergraduate degrees. Several English-based groups (where the institutional framework is more flexible, since students can always opt out into a Spanish group) have tried compulsory attendance, continuous evaluation and emphasis on homework assignments. In the last three years, four of these courses have been taught by foreign professors coming from institutions that routinely apply Bologna-like methodologies, and the results and the acceptance by the Spanish students has been closely monitored (with mixed results). Student reaction seemed to be heavily influenced by the specific profile and attitude of the professor involved, and his ability to positively engage the class. In all cases, however, there were complaints by students that could not attend the sessions and were therefore penalized. Three university sponsored pilots (one of them still running) have focused on improving teamwork and communication tools in a problem-based learning environment, making extensive use of interaction tools (such as electronic forums) and migrating to the web platform (Moodle based) on which the new degrees are supported.

These various pilots have confirmed the pedagogic potential of the "Bologna process" student-centric, outcomes-oriented methodologies. They have also, however, highlighted the significant hurdles must be overcome for their effective adoption in the Spanish engineering education environment, particularly when budget constraints are taken into account. Tackling these difficulties requires achieving the educational equivalent of the current manufacturing trend towards "mass-customization", in order to allow individually tailored learning paths with a level of resources similar to that required by standardized education.

These difficulties include:

- Resource requirements vs. availability. Pilots have highlighted the risk of the instructor's workload, particularly grading assignments, bursting out of control. On the other hand, and even more so considering the current economic climate and the sore status of the public finances, these reforms are generally being implemented under a "zero net additional resources" policy. That limits the approaches that can be implemented. "Craft-like" approaches that can be effective in the shift to a more active, participatory and student-centric methodology in smaller subjects can not be applied within existing resource constraints. Preliminary pilot results suggest that, unless course designs (and, particularly, evaluation procedures) incorporate elements specifically aimed at allowing scalability, these approaches can not be properly implemented with the current resources. Besides the need for additional resources, in some instances the need is for different resources, such as smaller, multi-functional classrooms, in which students can be rearranged in several working groups.
- Assessment process and motivation. This challenge relates to both instructors and students. Professors are evaluated and compensated according to their research output ("publish or perish"), with teaching being treated as a necessary evil. This complicates the implementation of pedagogical approaches that place heavy demands on their time and energy. As for the students, a substantial cultural and attitude shift towards assuming responsibility for their own development would be required, and it is not clear how to bring about this major change.
- Continuous evaluation. Conventional, individual written exams allow a reasonably accurate, fully individualized evaluation, which is hard to attain in a continuous evaluation environment, particularly if faculty resource constraints are taken into account.
- Consistency assurance. Guaranteeing a reasonable level of commonality in course contents and grading standards is harder to achieve in a proactive, student centered learning environment, where the learning is based to a substantial extent in a two-way interaction among the students and the instructor.

IV. GOING LIVE. COURSE DESIGN APPROACHES

To discuss the go-live experience, and therefore the implications of scaling up from the pilot experiences, this paper will focus primarily on the implementation project of a core (compulsory) second year subject of the computer engineering curriculum.

As discussed above, the potential synergies created by the simultaneous redesign of the various engineering curricula led to the creation of some subjects, corresponding to the list of the Engineering/ Architecture basic topics, which spanned all the engineering degrees. The subject analyzed in this paper, Foundations of Engineering Management (FEM), implements the "business administration" basic topic, and spans 7 different engineering degrees, from Telecommunications to Mechanical Engineering. This being a core (not elective) subject, this will result in a large number of parallel groups being taught in any given academic year. Since the implementation of these undergraduate degrees started in September 2008, and this subject is taught in the 2nd year, teaching started in September 2009 in 1 degree (Computer Engineering), and is scheduled to start in six more in the second quarter of this academic year (Feb. 2009). It may also be extended to the remaining existing degrees once they are converted, as well as to new degrees.

Designing the syllabus and teaching approach of new courses such as this requires taking coordinated design decisions at various levels. Decisions affecting the institutional and regulatory framework, as well as those involving shared physical infrastructures such as classrooms, must be taken at the University or School level.

A. Design decisions taken at the University or School level

Decisions taken at the UC3M or School of Engineering level include:

- Institutional framework for assessment procedures. University-wide guidelines governing continuous evaluation have been issued. A minimum of 40% of the grade has been allotted to continuous evaluation, with no minimum thresholds for either the continuous evaluation or the final exam. Attendance to laboratory sessions, however, can be made compulsory. Detailed provisions have been made for the case in which students do not attend the continuous evaluation; their final grade will be 60% of the final exam grade, even if for that particular course continuous evaluation accounts for more than 40%. Similar provisions apply to the "extraordinary", make-up evaluation that takes place in June-July for students that received a "fail" grade.
- Small groups for practical sessions. Each 6 ECTS subject involves, each of the 14 weeks that make up a semester, a 90 minutes large-group lecture for up to 120 students and a 90 minutes small-group session, in which each large group is broken up in 3 smaller groups. Evaluation takes place in the small groups. This is aimed at allowing a small group setting where interactive methodologies can be applied, while containing the overall cost impact.
- Multifunctional classrooms. The small-group sessions take place in smaller classrooms, specifically equipped to allow different seating layouts, including breaking up into small 6-member teams.

B. Design decisions taken at the course level

The lessons learnt from the previous pilots (discussed above), as well as the actual experience of those departments whose courses are located in the first year, and had therefore already faced these issues last year, was taken into account while designing the approach implemented in FEM this first quarter. This quarter's implementation experience, in turn, is being closely monitored in order to fine tune the approach for the second quarter and for subsequent years, as well as to serve as a basis for the design of subsequent courses by the same team. Furthermore, some of the approaches being piloted in this course will be presented to the management of the Engineering School, to analyze the potential of a wider implementation.

While incorporating all these elements into the actual design of the FEM, some detailed but nevertheless relevant additional issues arose. Several of them concerned the coordination of the small groups.

Splitting the large groups into several small groups requires that the course content is consequently divided in the components that can best be taught in a traditional lecture format and those that benefit from the interaction that smaller groups allow. The methodology for the small group sessions must also be defined. A sensible approach would be to use the weekly large group session to explain theoretical contents and use the other small group session to carry out practical exercises, case discussions and other activities that engage students in an active learning model. That was the rationale behind the two 90-minutes weekly sessions design decision.

That is, however, more easily said that done, since it creates a number of coordination hurdles:

- Large group-small group sequencing. Since practical sessions apply theory that must have been previously taught at the large groups, a precedence condition is created. Bank holidays affecting some sessions but not others alter this balance. Furthermore, actual experience during the first quarter highlights how otherwise minor alterations of the normal schedule become far more disruptive under this schema, e.g., time lost at some groups due to a student delegate election or to student satisfaction surveys.
- Weekly coordination among instructors in large and small groups.
- Since evaluation is carried out in the small groups, attendance and attitude in the large groups drop.

Another source of variability stems from the uneven attitude and profile of faculty members. Some faculty members can be reasonably expected to apply certain participative methodologies in a value-adding manner, while as others, if requested to apply them, may do so in a counterproductive way, leading to the dilemma of whether to allow heterogeneity in methodology.

Course-level design decisions that are being tested and monitored to tackle these challenges include:

- Stand-alone modules that can be taught in the small groups without precedence relationships. Some chunks of the syllabus are not excessively dependent on the rest of the components. They can be used to decouple the schedule of the various small groups; small groups that, due to the reasons mentioned above, find themselves "ahead" of the required theoretical contents simply devote a session or two to these semi-independent modules.

- Grading only some of the assignments. Grading only a fraction of the assignments or intermediate tests each student has submitted reduces grading workload, thus allowing more frequent and/or more complex assignments. A significant drawback is the generally negative attitude that students display towards sampling based grading. Various measures should be proactively taken to minimize this resistance, including clearly explaining upfront the whole grading procedure and its rationale and grading the same assignments for each student.

- Extensive utilization of educational IT tools. It encompasses fully exploiting the administration functionalities of Web based Learning Management Systems (such as Moodle©) to automate assignment collection, identify students that failed to turn in their assignments, etc. It also involves IT mediated grading, particularly through the utilization of test databases.

- Integrating antiplagiarism tools in the Learning Management System: The use of tools such as Turnitin© might help to deter plagiarism. However, using this tools, if not properly integrated with the LMS being used, increases the assignment administration workload. Use of widely utilized LMS's, such as open-source Moodle, increases the chances that antiplagiarism tools have been seamlessly integrated. This first quarter, an integration of Turnitin© into a Moodle-based LMS is being tested, with mixed results so far.

- Reutilization of existing educational material. Approaches such as using OpenCourseware can reduce the effort required by these participative methodologies.

- Integrating research projects into the pedagogic methodology. Actively engaging the students can be facilitated by involving selected students in actual research projects, as well as by including as a specific aim in the research projects the production of results that can enrich the educational process. In this specific case, a multi-year research project in which the whole Engineering Management group is involved provides both the setting for allowing particularly competent and motivated students to get an initial exposure to research, and a wealth of real-life problems, models and situations that are being used to develop the material for the practical sessions, thus leading to substantial synergies.

- Factoring attendance into the continuous evaluation. Initially, attendance was monitored in both the large and the small groups, with the idea of factoring it into the calculation of the continuous evaluation grade. It led, however, to classes in the large group being full of students that were there merely because they were forced to, who did not bother to listen and kept talking to each other, rendering the sessions quite hard to manage. The current approach is to make attendance to the large group sessions voluntary and to control attendance at the small group sessions.

V. Conclusions

The more tangible and formal EHEA elements, such as adoption of the three cycle structure, ECTS or Diploma supplements can be "imposed by decree" and will eventually be implemented. However, effective adoption of the supporting methodological and cultural elements, such as the shift towards an active learning, student centric, learning outcomes based approach is much less certain. On the other hand, implementing EHEA's formal aspects without adopting its methodological underpinnings could actually make things worse. The approaches and lessons discussed in this paper might be helpful in overcoming the stumbling blocks that hinder that implementation.

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Session 11F Area 2: Laboratory Experiences: on-site and remote environments - Didactics for experimentation

Dual Instructional Support Materials for introductory object-oriented programming: classes vs. objects

Aedo, Ignacio; Díaz, Paloma; Díez, David; Montero, Susana
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Towards the loose coupling between LMS and Remote Laboratories in Online Engineering Education

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Didactic videos about basic concepts on alternating current circuits

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Dual Instructional Support Materials for introductory object-oriented programming: classes vs. objects

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Abstract— **Visualizations are widely used in programming courses but the integration of these software tools into classrooms is not straightforward since there is a lack of information about the real benefits for learning and how to combine them with traditional lectures. We describe in this paper an experiment of using dual instructional support materials (textual and visual programs) in the lab classes in a Java-based CS1 course. The approach consists of two phases: students work the class concept in a traditional programming environment and the object concept in a visual environment as Greenfoot. The experiment shows positive results in terms of concepts understanding in students with no prior programming experience. Therefore we also suggest this as a possible way for integrating visualizations to the course.**

Keywords-component; Object-oriented programming, Visualization, Novice Programmers, Greenfoot

I. Introduction

Many studies have been carried out to know firsthand the main problems and difficulties in object-oriented introductory courses (CS1) both from the teaching and the learning point of view [1][2].

In a CS1 using an object-oriented language, it is crucial that students get a good understanding of key abstract concepts like object and class at an early stage [3]. Since in our degree on Computer Science we follow an approach that combines a strong start in basic constructs with early object-orientation [4], we are concerned with this issue.

Novice programmers do not have a concrete model in their everyday life to handle with these abstract concepts [5]. According to [6] between 75% and 83% of students are visual learners and, therefore, we could provide interactive visualizations for the students to concretize abstract concepts at the beginning of the course. Some of these visualization tools are devoted to help students “see” what an object actually is [7], as BlueJ [8], Greenfoot [9] or Alice [10].

Encouraged by this trend, we decided to use one of these tools in a first semester course in object-oriented programming with Java in order to engage students and improve their comprehension of the class and object concepts. However, the introduction of this software tools into the teaching practice is not straightforward since there is a lack of information about the real benefits for learning [7].

Consequently, using a visualization tool also implies to design a teaching strategy to make the use of such tools as efficient as possible from a pedagogical point of view. We have adopted an incremental approach separating and grouping concepts and stages. The class concept and the compilation stage are worked in a Java development environment. The object concept and its behavior are worked in a visualization tool for Java like Greenfoot, in which students’ programs can be run step-by-step or in continuous play mode without making changes in their source code. For that, we have developed several dual instructional support materials in order to work with the same examples in both environments.

In this paper, we describe the basis and motivation of our approach and present the experimentation developed to evaluate the impact of these dual material within our CS1 course.

II. MOTIVATION AND THE RELATED WORK

Research into novices’ understanding of object oriented has revealed several misconceptions and problems that concern the notions of class and object [3] and sequence of method calls and their effects on objects [5]. According to that and our experience, students have problems in the first stages of learning to understand the difference between classes and objects and between methods and their invocations.

Visual environments for teaching elementary object oriented programming have been developed in order to provide a concrete model to students and they might handle these abstract concepts [11], but there is little research into the effectiveness of such tools [12]. Moreover, it has been reported that the utilization of mere educational tools is not the best strategy. Students should also get acquainted with the professional programming environments they will use when working as professionals [13].

In [14] researchers attributed students' misconceptions about the execution of a sequence of instructions to the lack of distinction between the environment and the execution of a program, because both the class definition and the object creation were made in the same environment without a main program class.

Since we are aware of the very inconsistent results showed in different research studies, our perspective is that the program visualization should be used as a complementary resource but

CS1 students need also to face traditional programming environments.

In [15] researchers integrated the use of visualizations to students' preparation for exercise sessions as homework. Our study attempts to integrate visualizations during the lab classes in order to improve the aforementioned misconceptions.

III. THE TEACHING STRATEGY

In our classes, the learning resources are structured into didactic units about the fundamental concepts of programming and objected-oriented principles along with short exercises for further practice about the concepts. In lab sessions students develop these concepts by creating and writing programs using Java in the JGRASP[16] object workbench environment. One of the problems in traditional programming environments is that object behavior is not directly observable, but these environments allow students to get acquainted about general concepts relating to computation, such as source code, compilation, execution or declarations of fields and methods in the class. Complementarily, visual environments allow active interaction and experimentation with object instances and to explore behavior by dynamic access.

We argue that if students develop these concepts separately in two complementary environments (programming and visualizing), they will improve the understanding of them. Consequently we decided to develop dual instructional material that can be used both in a traditional programming environment and a visual environment. In the former environment, students will work the class concept and the compilation stage. In the second environment they will play their solutions in order to work object creation and invocation of a method on an object, and thus they will understand better the sequence, first object creation, after method call.

The overall objective is to provide students with additional support for the lab classes, allowing difficult abstract concepts to be illustrated and reinforcing more effectively, like the class and the object concepts.

Next, we will explain briefly the instructional support materials under study.

A. *Instructional Support Materials*

At the early stage of the course the class and the object concepts are worked through a typical early exercise where we model geometric figures. This domain is simple for students and it does not present an added difficulty in the domain knowledge.

In a first step, students are asked to represent the *Point* concept like a simple class whose attributes, *x* and *y*, are of Java's primitive types and getters and setters methods are defined. In a second step, two kinds of figures are introduced to show the collaboration between objects. The *Triangle* is a geometrical figure formed by three *points* and the *Circle* is formed by a centre point and the radius. Moreover, a UML representation of the classes is provided.

Students have to think about how to use the learned concepts to implement the solution. The development is done using jGRASP and the solution is seen in a visual environment.

IV. CREATING DUAL INSTRUCTIONAL SUPPORT MATERIALS

In order to create the visual instructional material, first we analyzed some of the most outstanding tools [11] and selected Alice [10], BlueJ [8] and Greenfoot [9]. All of them have its own website, books and papers that evidence that are well known and widely used. Moreover, these learning tools are recommended by Sun for users without programming experience [17].

During this analysis, we considered the following restrictions aimed at integrating the visual environment in the most efficient way in our CS1 course.

(i) Our students need to develop the basic java programming skills using proper syntax in order to accomplish assignments in this and other related courses. (ii) We cannot afford to spend a significant amount of class time teaching other environment, as well jGRASP, or event-driven concepts to support interactivity with GUIs. Indeed the main disadvantages of using visualization tools include the physical and cognitive overload required to use the tools both from students and teachers. It takes time to install and use the environment. (iii) The environment should allow us to represent visually the instances of classes described in our lab session material without changing the source code. Students have to experience how their code works to learn from their own mistakes. In the next paragraphs we describe the three tools we studied and how they fulfill or not our three requirements.

Alice (http://www.alice.org) is a 3D animation environment, developed at Carnegie Mellon University, in which objects and their behaviors are visualized. Its interface is based on drag-and drop manipulation of program components. Three-dimensionality provides a sense of reality for objects, but Alice hides the underlying language behind a "graphical" language, so it does not support teach text based programming.

BlueJ (www.bluej.org) is being developed and maintained at the University of Kent at Canterbury, UK, and La Trobe University, Melbourne. It provides a full Java environment in which the OO software project structure is presented graphically using UML-like diagrams. Users are able to create directly objects of any class by using icons, and then to interact with their methods. However, it does not display any visual clues about the object's state or behavior.

Greenfoot (http://www.greenfoot.org) was built by some of the same people who created BlueJ, so it is based on the Bluej platform. Greenfoot combines a Java IDE with a framework for producing Java programs that can be visualized in two-dimensional grid. This framework is based on a world environment with visual interactions between the world and the objects in it. Applications in Greenfoot are called scenarios.

TABLE I. VISUAL ENVIRONMENTS ANALYSED

	Alice	BlueJ	Greenfoot
Proper java syntax (i)	×Not text based programming	✓Full Java	✓Full Java
Java environment (ii)	×drag-and drop manipulation	✓Java IDE	✓Java IDE
Visual representation (iii)	✓3D	×icons	✓2D

Table I shows as the visual environments does cover (✓) or not (×) our restrictions to develop the visual instructional material. Greenfoot provides full java syntax, an integrated development environment, and 2D visual representation for our previous material.

Two Greenfoot scenarios were developed from the solution proposed for the exercises presented in the previous section (The point scenario and the geometric figures scenario). For each class, a visual class was created in the Greenfoot scenario. The aim was to minimize the student's contact with the way of programming in this environment, but providing concrete experiences with objects.

Fig. 1 shows a screen shot of the Geometric Figures scenario. The large grid area is called the "world" (1). In order to get a more real experience, a Cartesian coordinate system has been painted in which the geometric figures as objects will be created. The right side is the "class display" showing all Java classes involved in the scenario. From the bottom, the classes created by the students (2) are presented (Circle.java, Point.java and Triangle.java), and above them, the classes provided by the scenario (3) devoted to be a visual representation over the world (Circle_Greenfoot.java, Point_Greenfoot.java, and Triangle_Greenfoot.java). The way to interact with objects is through their methods showed in a context menu (4).

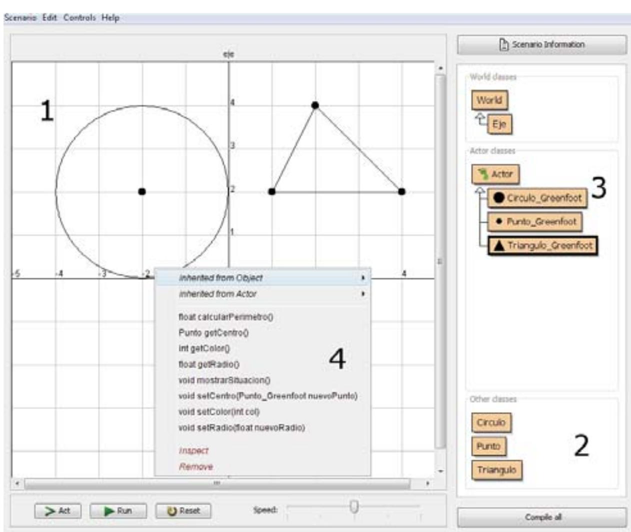

Figure 1. A screen shot of the Geometric Figures scenario

V. EVALUATION STUDY

We performed an evaluation study aimed at: (i) investigating the effect of using these dual instructional support materials in learning and (ii) examining whether these materials might contribute to better understand some basic object oriented concepts.

Two groups of students participated in the study. One group worked with the dual instructional material (GG, 15 students) and the other group just with the material for the jGRASP environment (CG, 18 students). All the students had roughly the same level of academic preparedness since those students with previous knowledge in Java were excluded from the study. Therefore, the concepts of object orientation in Java were new to all the participants.

Before the experimental sessions, the theoretical concepts were explained in common lectures. Two sessions were carried out to perform the scenarios described in the previous section. In both sessions the control group (CG) only used jGrasp whilst students in the other group (GG) were additionally asked to play their programs using Greenfoot. Sessions in this second group lasted a bit more since a briefing on the use of Greenfoot was required. Moreover, in their second session they were also asked to fill a questionnaire on the Greenfoot utility and usability as described below. Table II summarizes the experiment schedule.

TABLE II. EXPERIMENTAL PROCEDURE

Pre-experiment	Both	Lectures on theoretical concepts Class, methods, objects, instance, method call
Session 1	Both	Q1
	Both	Programming SC1 in jGRASP
	GG	Visualizing SC1 in Greenfoot
Session 2	Both	Programming SC2 in jGrasp
	GG	Visualizing SC2 in Greenfoot Q2
Session 3	Both	Q1

A. *Instruments for Data Collection*

We collected students' data and opinion using two types of anonymous questionnaires.

Table III shows the first type of questionnaire (Q1). It was aimed at identifying the level of understanding of concepts. It was filled for the first time at the beginning of the first session before performing the Point scenario (SC1). It consisted of a number of open questions where students described in her own words the concept of class, object, method, how an object is created and how methods are invoked. The students were not notified about the test in advance. This questionnaire was filled again at the end of the second session to measure students' progress in understanding concepts.

TABLE III. QUESTIONS FOR Q1

Evaluation Questionnaire - Q1
What is a class?
What is an object?
How is an object created?
What is a method?
How is a method called? Give an example if necessary.

The second questionnaire (Q2) was devoted to evaluate Greenfoot usability and its utility to improve the understanding of object oriented concepts, as demonstrated *in* Table IV. It was filled by students in the GG group at the end of the second session. This questionnaire had a number of closed questions in which a five-point Likert scale ranging from *none* (1) to *a lot* (5) was used to choose the response that best represented her opinion relative to features of the tool and scenarios. It also included a section with open questions where students were asked to express their opinions to enhance the dual instructional material and the experience.

TABLE IV. QUESTIONS FOR Q2

Evaluation Questionnaire – Q2
How easy is to use Greenfoot?
How easy is to visualize your exercise solution in Greenfoot?
How useful are the scenarios to understand the difference between class and object?
How useful are the scenarios to understand the creation of an object?
How useful are the scenarios to understand the state of an object?
How useful are the scenarios to understand the method call?
How useful are the scenarios to understand the collaboration between objects?
Would you like to visualize the rest of lab exercises in this environment?
How useful is the Point scenario to understand the object-oriented basic concepts?
How useful is the Geometric Figures scenario to understand the object-oriented basic concepts?
Do you think that the visualization is a good mechanism to understand better the object-oriented concepts or the jGRASP environment is enough?

B. Data Analysis and Results

For the sake of clarity we will structure the data analysis and results into two parts: the effects on learning outcomes and the students' perception about the usability and utility of the material.

Because we were interested in exploring whether there is a significant difference among groups before and after the experiment, we made an analysis based on the scoring of the students' answers for Q1 in a range from 0 to 10 points. Our hypothesis was that "if the groups could be considered equivalent in knowledge before the experiment, and after it they had significant differences, these differences could be attributed to the dual instructional material".

The data in Table V summarize the students' score for the questionnaire Q1, before and after the lab sessions. For each group we have identified the minimum and the maximum value for scores, the median and quartiles, and the standard deviation (SD) in order to have a first perception of the group equivalence.

TABLE V. MEASURES FROM Q1 SCORE

	GG (15 students)		**CG (18 students)**	
	Before	***After***	***Before***	***After***
Minimun	0	3	0	0
Maximun	6	10	7	9
Q1	1	6,5	1	4,25
Median	4	8	3	6,5
Q3	5	9	4	8
Mean	3,13	7,46	2,67	5,67
SD	2,13	2,16	2,25	2,68

Students from GG and CG found difficult to answer Q1 before the practical sessions, with a mean of 3.13 and 2.67 respectively. Since our groups are not formed by random assignment, an independent sample T-test was used to analyze the equivalence between GG and CG using the values of column before. This showed not statistically significant difference between GG and GC ($p= 0.5535$), so we can assume both groups were equivalent in knowledge before the experiment.

The column after shows Q1 score after finishing the second lab session. Students from GG increased their mean to 7.46 whereas CG only to 5.67. This shows a significant statistical difference between both groups ($p =0.0457$). Moreover, these results support the research made by [15] in which visualization was used to prepare the exercise sessions.

The Figure 2 shows in percentages the students' progress by ranges: a decrease in the grading (-10 to 0), an increase of three points (0 to 3) and an increase of more than four points (4 to 10). Most of students improved their grading after the practical work, but in GG even a 60% increased their grading in more than four points compared to a 44% percent in CG. Moreover, in GG no student decreased its grading whilst in CG a 6% got lower grades.

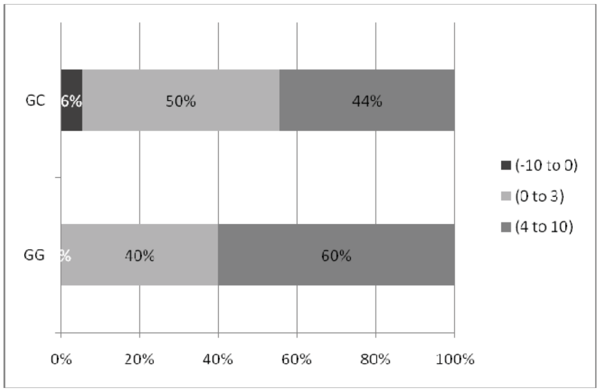

Figure 2. Percentages of the score improvement for Q1

Table VI presents the percentages of improvement for each concept asked in Q1. GG improves in almost all concepts, less in the concept of class. These data allow us to confirm the initial idea about the benefits of each environment. CG used just jGrasp in which the structure of class and the object creation are the necessary elements to run a program, whereas in Greenfoot scenarios students have to interact with objects through method calls. Results support our initial hypothesis that the dual material improves learning outcomes and suggests that practice in terms of exclusively programming might be not enough to understand abstract concepts. Comprehension of such abstractions might require special techniques like visualization.

TABLE VI. THE IMPROVEMENT PERCENTAGE FOR EACH QUESTION

	GG(Greenfoot)	CG
Class	46,67 %	66,67%
Object	60 %	44,44%
Instantiation	66,67 %	66,67%
Method	60 %	44,44%
Call a method	73,33 %	16,67%

With regard to the students' perception in the use of the dual instructional material, all students considered program visualization as a good mechanism to understand better the object-oriented concepts. About the usability of the Greenfoot scenarios, most of the half students perceived as easy to use Greenfoot (60% quite a lot to a lot) and easy to display the scenarios (60% quite a lot to a lot). Students (60% quite a lot to a lot) found the Greenfoot scenarios as more useful to understand the concepts of call methods and collaboration between objects.

Finally, although the scenarios seem to be useful learning resources from the obtained results that perception is not shared by students. Just 53 % considered the point scenario as useful and 40% for the geometric figure scenario. This is a typical problem in CS1 where examples do not solve any real problem so students do not perceive their utility [18]. However, complex scenarios are also difficult to visualize.

VI. CONCLUSIONS

The systematic utilization of educational tools for teaching programming is well documented in the literature. Visualization is considered as a mechanism to concretize teaching and provide students with visual feedback to reinforce their understanding.

We have studied if the use of dual instructional material (textual and visual representation of programs) could improve the understanding of the basic object oriented concepts. According to the results here shown, the use of the dual instructional material benefits learning: we found students using the visualization performed significantly better the questionnaires about object oriented concepts. Therefore, we recommend the use of this kind of materials for reinforcing.

In addition, other benefit of this kind of instructional materials is that students and teachers do not spend extra time learning a visual environment and how to program with it. Students keep learning syntax, resolving compilation errors and working with professional environments.

These results can be considered as preliminary since only one experiment was performed. However the statistical significance of the result encourages us to continue exploring this approach. In fact we are currently working on developing more scenarios and improving the visualization process in order to tolerate better the errors in the students' programs and to unify the visual and the textual environments.

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Towards the loose coupling between LMS and Remote Laboratories in Online Engineering Education

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Abstract— **In this paper, we are providing a study on the issue of interoperating Learning Management Systems (LMS) and Remote Laboratories, in a seamless integration. This study emphasizes the need to make Remote Laboratories seen as a pedagogical material within the LMS. We are presenting a novel and original approach to make these two types of platforms communicate (LMS and Remote Laboratory) under a loose coupling relationship. The main purpose of this work is to bring a better follow-up of students to the tutor and the students themselves, and therefore to lead to an enhanced learning experience. (Abstract)**

Keywords- Remote Laboratories, Distance Learning, Learning Management System, Interoperability, Learning experience, Hands-on Approaches, Personalized Learning, IMS-LD, SCORM.

I. INTRODUCTION

Remote training services exploded with the growth of the Internet. Information Technologies and Telecommunications appeared therefore as a keystone for the leverage of Remote Laboratories (RLabs) in Distance Learning curriculum. Before the last few years, ongoing research in Distance Learning primarily focused on conceptual teaching or case studies, in the form of remote courses, works directed remotely or remote projects, but without possibility of real practical activities.

Hands-on approaches however are mandatory in scientific and technical education, especially in engineering curriculum [1]. Mainly, this study emphasizes that hands-on approaches help the students in making the link between theory and real problems, in supporting motivation and curiosity, in contributing to their personal development, in building socials networks. Because heavy and expensive industrial et laboratories facilities can neither be moved nor easily duplicated, a lot of efforts were made for the development of platforms, which now allow remote interactions between geographically distributed users and a pedagogical materials hosted in the school [2,3,4,5], laboratory [6] or company walls [7]. In these publications, all researchers accord to observe that it is not enough to create an interactive Web Site: it is compulsory that the conditions of experiments are realistic, productive and protected. In Distance Learning, one could add that interoperability is another mandatory characteristic, as Learning Management Systems (LMS) are the containers of remote learning activities and student's follow-up, and they are not yet able to include remote hands-on activities, while they already host lectures, tests, etc. Remote practical works are therefore ignored, because excluded since of their low interoperability, from the LMS. This paper addresses the problem.

In this paper, we are primarily interested in the interoperability between any Learning Management System and any Remote Laboratory. We identify the LMS as the element in the Information System that endorses the role of exposing the teaching contents on line while ensuring the follow-up of the user learning throughout his course of study. The purpose of this article is therefore to propose new models of interactions between these two types of platforms (LMS and Remote Laboratory) for a better follow-up of students, and therefore an enhanced learning experience.

The paper is organized as follows. Section 2 introduces a presentation of LMS in the light of relevant elements for integration with Remote Laboratories. Section 3 presents some elements of today's architecture for most common Remote Laboratories. Section 4 presents our approaches to make the two previously exposed architectures interoperate. Section 5 concludes.

II. Learning Management System (LMS)

In order to face problems in Education and life-long learning, such as the fast evolution of pedagogical materials and contents, many institutions and companies have turned towards e-learning, which makes it possible to learners, to acquire knowledge and competences without having to move of their place where they live or work. This calls the citation from Jesus del Alamo: “"If you can't come to the lab, the lab will come to you” [8]. In order to facilitate the organization and the success of these new ways of learning, software solutions appeared, known as “Learning Management Systems” (LMS). LMS are platforms created for managing remote curriculum and teaching through the Internet, while also proposing an electronic follow-up of the students throughout their learning experience.

The LMS are Web applications, which provide to their users (designer, tutor, learner, coordinator, and system administrator or super user), a set of tools ([9], [10], [11], [12]), or services allowing especially for:

- The designer:
    - To build and maintain his/her pedagogical materials by integrating resources and activities of any type according to a hierarchical structure carried out according to the standards, mainly at the SCORM (Sharable Content Object Reference Model [13] or IMS-LD (Instructional Management Systems-Learning Design [14]).
- The tutor:
    - To organize the groups of training and to determine the parameters and the processes of the training sessions.
    - To carry out the follow-up of the students.
- The learner:
    - To reach and follow courses according to their own rhythm, auto-evaluation using tests constructed and carried out according to IMS-QTI specifications.
- Both the tutor and learners:
    - To communicate in a synchronous way (chat) or asynchronous (mails, forum, shared documents).

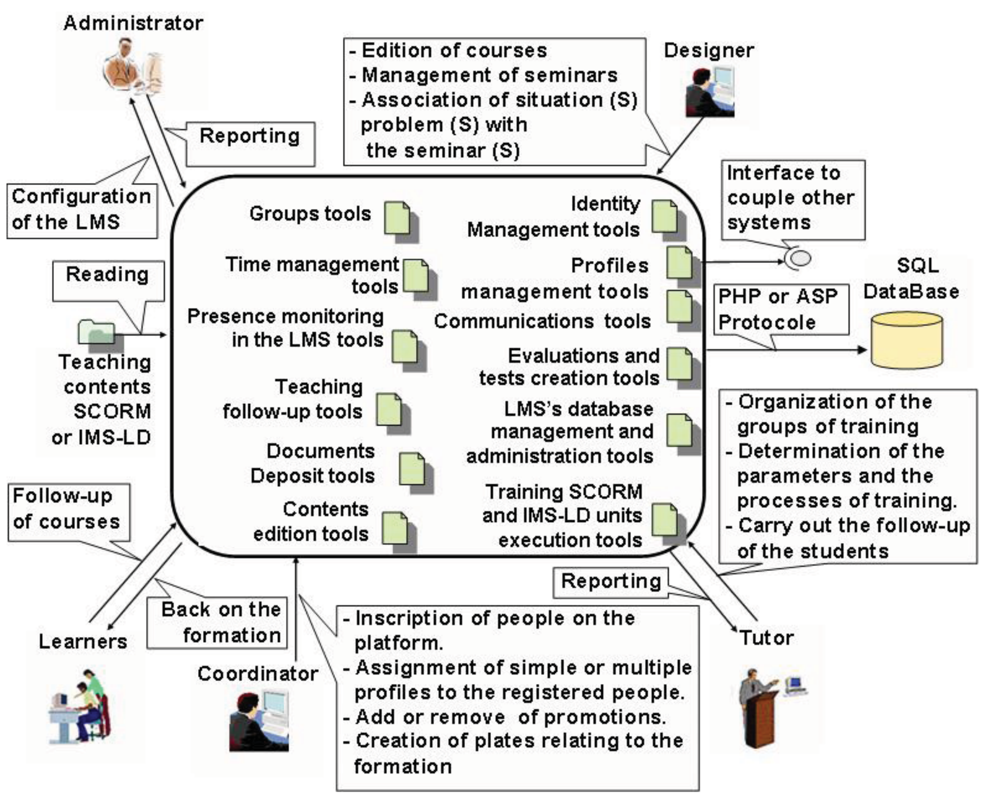

Figure 1. Figure 1 : LMS's components and Functioning principle

- The coordinator:
    - To register people on the platform.
    - To assign simple or multiple profiles with the registered people.
    - To add or remove of promotions.
    - To create areas relating to a module of training.
- The administrator:
    - To configure the platform according to the desired organization.

The Figure 1 shows the common most frequent components, which can be met, in a given LMS, as well as the functioning principle of this last one.

III. REMOTE LABORATORIES

The remote laboratories are referring to practical works carried out remotely on real devices under the assumption of a learning experience. Learners, tutors as well as devices to be handled are not in the same place. A typical architecture for the remote laboratories is given on figure 2.

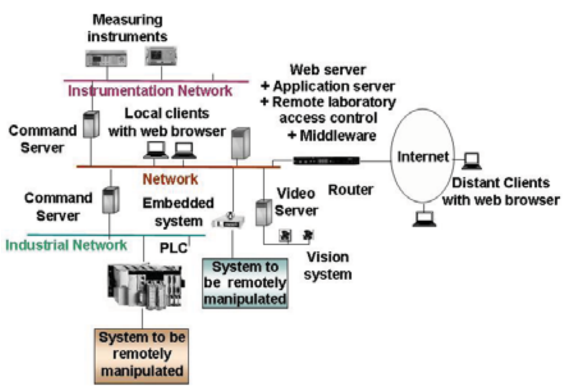

Figure 2. Figure 2: Typical Remote laboratory structure

The common software architecture is composed as follows (figure 3): the device itself, a local computer connected to the device, which plays the role of a gateway between the device and the remote computer of the user, and the associated middleware, through which information is exchanged between the local and the remote computers. There is, of course, a reason why this architecture is so widespread. In fact, most of devices must be locally handled by a computer in order to be remotely controlled over the Internet. There is no denying that some device directly embed an Internet connection, but this is only because they embed a modern operating system inside the device, which therefore does not require a dedicated local computer; yet it does not make much difference in the presented architecture: local computer (would it be embedded in the device itself or as a separate computer linked to the device, middleware, and remote Graphic User Interface (GUI)).

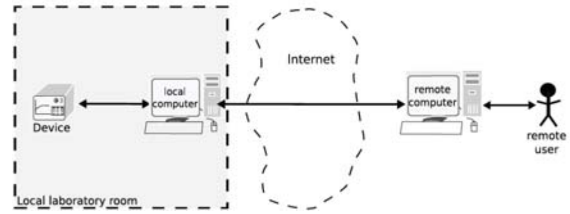

Figure 3. Figure 3: The widespread software chain of remote laboratories.

but to build a middleware allowing remote clients to connect to the local computer that handle the device. That is the reason why the first remote laboratories were using software solutions such a VNC1, as it provided them the remote control over the local computer connected to the corresponding device. Nonetheless, those solutions were given up as they lack security and they require a lot of bandwidth, in favor to software development following the Distributed Architectures paradigms, such as Service-Oriented Architecture.

This evolution was mandatory to open the Remote Laboratory middleware to the other services in the Information Systems, and especially to Learning Management Systems, as we will study it under the following section. The connection between LMS middleware and RLabs middleware is at the core of our approach.

IV. A NEW APPROACH TO COUPLE A LMS AND A RLABS.

As already evoked in section 2, many institutes have already included remote formations in their curriculums. However, these platforms, largely used today, are not designed to integrate remote practical works, whereas remote practical works propose to put the theoretical teaching into practice, they are found excluded from the LMS, for lack of sufficient software technologies. The fact that the RLabs session is unlinkable to a Learning Object in the LMS at the moment comes with strong drawbacks:

- all the situations of training are hardly proposed online, and especially,
- no follow-up of students can be proposed during remote hands-on approaches,
- no authoring tool for setting-up the associated learning scenario,
- no possibility for the student to easily confront experimental results towards his/her theoretical exercises conducted in his/her LMS session.

It has to be noticed that especially the latter one (decreasing the learning enhancement by putting technological barriers between theoretical and practical learning experiences) strongly violate the first principle of laboratories in general,

[1] Virtual Network Computing

which are designed to let the students making theory and practice meet during the same learning session.

We therefore think that part of ongoing research in RLabs should focus on making RLabs and LMS converge. The gap [13] between platform of remote practical works and the LMS is due to the fact that remote practical works require specific developments. They are thus stored in platforms' owners, while no standard exist for RLabs. As for LMS standards, such as SCORM [14] or IMS-LD [15], nothing is designed for RLabs, because so far those standards did not excepted the pedagogical content to be hosted outside the L(C)MS2. Moreover, it is difficult to imagine to host all the remote practical works in a LMS, in the same way that lectures or directed works, which requires much less interactivity between learners and educational contents.

This said, a pragmatic solution to integrate RLabs within an LMS, would be to carry out a loose coupling, between these two platforms through an interface in the forms of modules or "plug-ins", allowing to connect any RLab to any LMS, as long as the shared vocabulary and data exchange protocol (the module of the LMS, and its correspondent for the RLabs) is available on both parties.

Our research tasks thus initially concentrated to make a research on the platforms of LMS having a plug-in system. After a long bibliographical search we discovered that there do not exist academic documents covering this kind of subject. In practice existing LMS (e.g: Moodle, Claroline, etc.) allow the use of third-parties libraries through a plug-in system.

One can afterwards recover information on the set of "widgets" W = {w1, w2, …, wn} used in the remote GUI of a RLab (whatever the technology of the RLabs). It is therefore possible to store the set of widgets of each RLab in a repository, which could be queried afterwards, so that the remote GUI could be instance on the fly, after the set of widgets delivery. If this set of widgets is hosted in the LMS and seen as usable resource in learning scenario in LMS, the connection between LMS and RLabs become effective. Indeed, the LMS have the knowledge and comprehension of the widgets, and the RLabs is built upon instantiation from the widgets retrieved within the LMS. The widgets are therefore the keystone for interoperability between LMS and RLabs.

In this study, the aim was not to reinvent the wheel as for a widget repository for RLabs. [16], [17], and [18] proposed an architecture which make it possible to display a set of "widgets" by making an entry from a Unit Of Learning (UOL) in the IMS-LD standard. Thus while proceeding to small improvements of this architecture, we think that it is possible realizing the development of some modules and "plug-ins" of extensions, to use it as bridge or interface to couple in loose manner, an LMS and a remote "Widgets Laboratories".

[2] Usually the difference is made between the LMS, which expose pedagogical content to the students and tutors, and the LCMS, meaning Learning *Content* Management Systems, which is held responsible for providing authoring tools and scenarii engines. In this paper, we are using the stretch of language where LMS denotes both the LMS and the LCMS.

Thus, this is the approach, which we try in this research project, to realize by proposing a new architecture allowing to remotely controlling a system via its deported GUI, made up by a set of "widgets".

A study of the functioning of "Wookie" [18], showed us that it is possible to make this coupling while making:

- An entry from a UOL (Unit Of Learning) IMS-LD according to the architecture of figure 4.
- A simple entry (i.e. not from an IMS-LD scenario) from the LMS according to the architecture of figure 5.

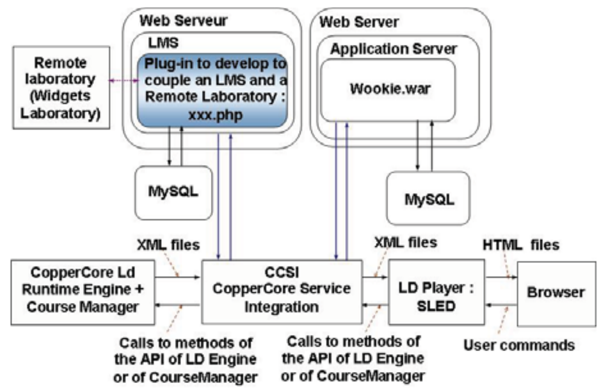

Figure 4. Figure 4 : LMS Remote Laboratory Coupling with an entry from an UOL IMS-LD

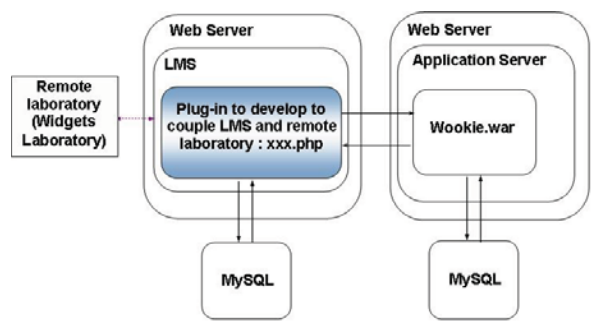

Figure 5. Figure 5 : LMS Remote Laboratory Coupling with a simple entry from the LMS

The Plug-In, in these two architectures carries out the two following principal operations:

- Request "Wookie" to have an instance of the "Widgets" to deploy in the LMS to command the instrument or the system,
- Parse the response sent by "Wookie" to create a GUI of the command of the instrument or system in the LMS.

We chose in a first step to work within second architecture assumption, by leaving an entry from a IMS-LD scenario in second step, as it lead us to use all the chain composed by : SLED, CopperCore, and CCSI ([19], [20], [21]).

Wookie responds to request (GET request for a widget/set of widgets instance) by sending a response in XML form, about information relating to the “widget” or the whole of the “widgets” for which it was requested.

Typical responses from the Wookie server is as follows:

- For one widget:


```
<?xml version="1.0" encoding="UTF-8"?>
<widgetdata>
<url>http://localhost:8080/wookie/wservices/www.getwookie.org/widgets/W
P3/natter/chat.htm?idkey=Mtw6vPPVApb6kbJUkBbFXQzEPuw.eq.&amp;pr
oxy=http://localhost:8080/wookie/gadgets/proxy&amp;st=0%3Atestuser%3A
http%253A%252F%252Fwww.getwookie.org%252Fwidgets%252FWP3%25
2Fnatter%3Awookie%3A%252Fwookie%252Fwservices%252Fwww.getwoo
kie.org%252Fwidgets%252FWP3%252Fnatter%252Fchat.htm%3A0%3AMt
w6vPPVApb6kbJUkBbFXQzEPuw.eq.</url>
<title>Natter</title>
<height>383</height>
<width>255</width>
<maximize>false</maximize>
</widgetdata>
```


- ***For a set of widgets:***


```
<?xml version="1.0" encoding="UTF-8"?>
<widgets>
    <widget id="http://www.myhost.org/widgets/default/chat">
        <title>Chat</title>
        <description>This widget provides a simple chat or
Instant messaging facility</description>

    <icon>http://localhost:8080/wookie/shared/images/chat.png</icon
>
        <parameter>widget=unknown</parameter>
    </widget>
    <widget id="http://www.myhost.org/widgets/default/forum">
        <title>Forum</title>
        <description>This widget provides a threaded
discussion forum faciltity</description>

    <icon>http://localhost:8080/wookie/shared/images/forum.png</ico
n>
        <parameter>widget=unknown</parameter>
    </widget>
    <widget id="http://www.myhost.org/widgets/default/vote">
        <title>Vote</title>
        <description>This widget provides a voting
facility</description>

    <icon>http://localhost:8080/wookie/shared/images/vote.png</icon
>
        <parameter>widget=unknown</parameter>
    </widget>
    <widget id="http://www.getwookie.org/widgets/weather">
        <title>Weather</title>
        <description>A silly Weather widget</description>

    <icon>http://localhost:8080/wookie/wservices/www.getwookie.or
g/widgets/weather/icon.png</icon>
        <parameter>widget=unknown</parameter>
    </widget>
    <widget id="http://www.getwookie.org/widgets/WP3/natter">
        <title>Natter</title>
        <description>basic chat widget</description>

    <icon>http://localhost:8080/wookie/wservices/www.getwookie.or
g/widgets/WP3/natter/Icon.png</icon>
        <parameter>widget=unknown</parameter>
    </widget>
    <widget id="http://www.schulz.dk/pacman.xml">
        <title>PacMan v2.6</title>
        <description>Google Gadget</description>

    <icon>http://localhost:8080/wookie/shared/images/defaultwidget.p
ng</icon>
        <parameter>widget=unknown</parameter>
    </widget>
    <widget
id="http://www.labpixies.com/campaigns/clock/mini_clock.xml">
        <title>LabPixies Clock</title>
        <description>Google Gadget</description>

    <icon>http://www.labpixies.com/campaigns/clock/images/mini/th
umbnail.jpg</icon>
        <parameter>widget=unknown</parameter>
    </widget>
    <widget
id="http://www.labpixies.com/campaigns/todo/todo.xml">
        <title>ToDo</title>
        <description>Google Gadget</description>

    <icon>http://www.labpixies.com/campaigns/todo/images/thumbna
il.jpg</icon>
        <parameter>widget=unknown</parameter>
    </widget>
    <widget
id="http://www.labpixies.com/campaigns/weather/weather.xml">
        <title>Live Weather</title>
        <description>Google Gadget</description>

    <icon>http://www.labpixies.com/campaigns/weather/images/thum
bnail.jpg</icon>
        <parameter>widget=unknown</parameter>
    </widget>
</widgets>
```


As for authoring of the RLabs possibly connected to a LMS, the process is to describe a set of widgets in the Wookie fashion, setting a package for “Wookie” [23], and then to used it as a UOL in the learning scenario hosted by a LMS compliant with IMS-LD. This also means that the RLabs is reusable through different LMS, as long as it supports IMS-LD standard (loose coupling).

However, while processing in this way, there is not enough loose coupling, in our opinion. The main issue is that Wookie repository of widgets is populated from its config file describing the widgets (a set of widgets according to the W3C standard with its file config.xml, containing the URI of the start page as well as metadata, and loaded in “Wookie” via the its admin pages of this last one [22]). This is however compulsory if we want to connect an existing RLab to Wookie without having to reengineer its widgets. In order to solve this problem, we think that it is possible to modify the source code of “Wookie”, so that it could import these informations from the RLabs itself. A first simple solution consists in introducing these informations directly into the database of “Wookie”. Another solution is under study as we are conducting research in this matter, and especially using the Web 3.0 (ontologies) to represent the GUI of a RLabs in our RLabs framework (called OCELOT [23]). Such ontologies could be aligned with the concepts and relationships proposed by Wookie so that the widgets issued by such a framework could automatically be populated in the associated wookie meta-widget representing the RLabs, and allowing the connection with the LMS thanks to IMS-LD.

V. CONCLUSION

In this paper, we tried to a new approach which tries to close the gap between LMS and RLabs. The main issue is to find a solution to use the Rlabs in the UOL (Unit Of Learning), conform to standard IMS-LD, so that the walkthrough of the student during RLabs session could participate to the LMS follow-up of the student.

The main result is a loosely-coupled approach based on existing software which allows the follow-up of students during RLabs sessions through their use of predefined widgets expressed in a Wookie server, which are themselves usable in a UOL in IMS-LD standard. The biggest open issue is the provisioning of the Wookie server. Several means are under study, from standard insertion in database, to automatic provisioning through ongoing research in ontologies alignment, but each of these should still be tested in a real experiment in a broader audience in order to gather data on their scalability. Future works will consist in studying different granularity of expression for the widgets, in order to refine the follow-up of students during RLabs session in their learning walkthrough, so as to as better learning experience could be delivered to both the students and the tutors.

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Didactic Videos About Basic Concepts On Alternating Current Circuits

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Abstract—**This work emphasizes the importance of the formulation and application of didactic videos mainly in subjects where the classes are exclusively theoretical, as in the case of the subject ET016 – Electrotechnics, taught at the School of Electrical and Computer Engineering – UNICAMP. It is mandatory and it is offered to the students of the following Colleges: Food Engineering, Agricultural Engineering, Control and Automation Engineering, Mechanical Engineering and Chemical Engineering. In this subject, basic concepts of electricity are taught: single-phase and three-phase circuits; electrical energy production, transmission and application; physical principles and main application of transformers; electrical machinery of induction, asynchronous and direct current; and basic concepts of electric installations and protection devices. Upon elaborating and making these videos available, we aim at arousing a larger interest on the students, causing them to complement and reinforce the content taught at the attended theoretical classes.**

Keywords - Alternating Current Circuits, Electrotechnics, Engineering Education, Didactic Videos.

I. INTRODUCTION

Historically, in the period from 1970 to 1980, there was a subject named ET515 - Electrotechnics at the School of Electrical and Computer Engineering (SECE) - UNICAMP - Brazil, lasting six hours weekly, with four hours in the classroom and two hours in the laboratory. From 1981 on, the subject ET616 – Electrotechnics started being taught using two hours in the classroom and two hours in the laboratory and from 2004 on, we also took the responsibility to teach the subject ET016 – Electrotechnics, with just two hours weekly in the classroom. Detail: all these subjects have the same summary imposed by the respective receiving courses.

Currently, ET616 and ET016 are offered to students from the following Colleges: Food Engineering, Agricultural Engineering, Control and Automation Engineering, Mechanical Engineering and Chemical Engineering. In these subjects basic concepts of electricity are taught: single-phase and three-phase circuits; electrical energy production, transmission and application; physical principles and main application of transformers; electrical machinery of induction, asynchronous and direct current; and basic concepts of electric installations and protection devices. ET616 e ET016 do not have the same level of complexity as similar subjects offered to the students at the SECE.

Before the inescapable quality loss in transmission and the resulting assimilation of the content mentioned above, allied to our taking priority in the activities of the graduation teaching, and being aware about the students need in having a fundamental knowledge of good quality on alternating current circuits, the means we found to reduce such loss was the production and broadcasting of videos with exhibition of experiments, which are not accomplished by the students who currently attend ET016.

Among the achieved objectives with the formulation and application of the videos up to now, elaborated by us, we stand out:

- Greater interest aroused in the students in complementing and reinforcing the taught content at the attended theoretical classes.
- Flexibility in accessing for the videos and the didactic material are available via Internet.
- The production of didactic videos may be useful in several teaching, researching and extension areas, concerning the information broadcasting in a dynamic way, enabling that real laboratory experiments, which not always may be reproduced

wherever one wishes, to be accessed by anyone interested in them.

Other important comments and analyses about the importance of the use of didactic videos, and how the recording must be done with details and precision in its captures, so that it becomes clear, having no illumination and image framing problems may be found at all references [1 – 8].

II. ELECTROTECHNICS DIDACTIC VIDEOS

From elaborated scripts in experimental rehearsals, we produced didactic videos for the following presented topics, making a brief comment on the presented script.

1. Voltage-Current Characteristic: an experimental procedure to obtain the relationship between the applied voltage and the resulting current (characteristic curve) in a two-terminal device (6’58”).
2. Root Mean Square (RMS) Concept: a visual approach about this concept and experimental confirmation of the rms value of a sinusoidal voltage (3’53”).
3. RC Series Circuit: sinusoidal steady-state behavior of a RC (resistor-capacitor) series circuit connected to a sinusoidal waveform generator (4’02”).
4. RL Series Circuit: sinusoidal steady-state behavior of a RL (resistor-inductor) series circuit connected to a sinusoidal waveform generator (4’28”).
5. RLC Series Circuit: sinusoidal steady-state behavior of a RLC (resistor-inductor-capacitor) series circuit connected to a sinusoidal waveform generator with variable frequency (4’27”).
6. Unbalanced Three-Phase WYE-connected Load: the importance of the fourth wire in an unbalanced three-phase wye-connected load (3’00”).
7. Three-Phase Voltages: experimental observation of the relation between line and phase voltages on a three-phase system (3’02”).
8. Power Factor Correction: the importance of the power factor correction of a single-phase induction motor through the connection of capacitors in parallel (4’48”).
9. Rotating Magnetic Field: an elementary experiment shows the operating principle of a three-phase induction motor (5’01”).
10. Simple Type Switch: a switch is one of the most basic yet important devices in an electrical installation. This movie teaches how to install a single pole switch to turn on and off one or more lamps from a single location (2’43”).

Fig.1 - Examples of Screen from the Videos

11. Three-way Switch: it is specially designed to work in pairs and this movie call attention how to install this kind of switch to turn on and off one or more lamps from two places (3’17”).

12. Four-way Switch: it is designed to work with the three-way switch. This movie teaches how to install two three-way and one four-way switches to turn on and off one or more lamps from three locations (4'05").
13. Residential Connections in the Electrical Network: some concepts about the connection of the residential power grid (3'00").
14. DC Motor Starter: this movie shows how to start a DC motor without large starting current and how to protect against excessive speed when the field current is low (5'20").
15. Starting of Induction Motor: how to use a star-delta device to prevent a large starting current in a three-phase induction motor (5'05").

Note : the information in brackets, as in (5'01") for the Electric Motors movie, means the length of the film in minutes and seconds.

For a higher easiness in accessing, these videos have been available at the Youtube Website, with audio in Portuguese. The screens example of the elaborated videos may be seen in Fig. 1.

III. METHODOLOGY

The movies have been created with the following technical characteristics to make the access over the dial-up connection internet easier:

- Average run up to 5 minutes per video
- 15 frames/s: 320 x 240 pixels.
- Video for broadband connection: 150 Kbps.

The first equipment used was a Digital Nikon Coolpix 7600 - 7MP (Digital Camera) and now we have a camcorder JVC – GZ – HD3U.

The final video image editing has been accomplished through "Windows Movie Make" which is available for Windows XP and Windows VISTA users, Fig. 2.

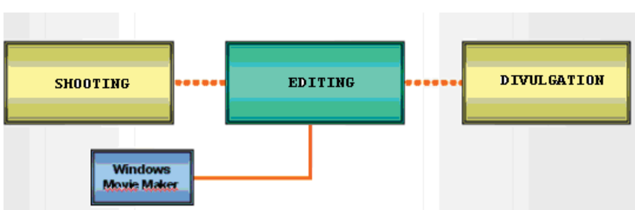

Fig.2 - Editing Scheme of the Didactic Videos

The main subjects addressed on the videos have been complemented with Circuit Illustrations, Electrical Diagrams and Formulas, placed in before and/or after the exhibition of the experiment shooting, aiming at determining the theme addressed on the video.

IV. RESULTS

As mentioned above, the videos about basic experiments on alternating current have been available at the most popular video website of internet, the Youtube (www.youtube.com) and they can be found through the terminologies ET016 and ET616 (subject acronyms). The receptivity of these movies is presented on Table 1.

The students may watch and comment the content of the movies on the Website. Remarks about the movies, video contents and their didactic means of exhibition have been constant on the received messages. As an example, we present some of the comments:

- "I am an electronic technician and I find these subjects very interesting. Congratulations on the teacher's explanation!"
- "Very good. This is the kind of video that I enjoy watching. I suggest that you improve the sound of the next videos and also insert subtitles in Spanish. Congratulations."
- "Very Good!!!!"
- "It helped me a lot, and solved many of my doubts. I admire the work of Professor Barreto very much. I have read his thesis on the manufacturing of an electric vehicle, and I admit that it was one of the best materials I have ever found.The details and technics presented are fantastic."

We know that these videos are being adopted as didactic material at other Universities and Technical Schools.

The importance of this subject in the professional life of engineers has been evidenced through the messages we have received from former students, as well as requesting access to didactic material available over the internet through the TELEDUC environment:

- "The material will be very useful to review the concepts learned from the subject that you teach".
- "I would like to ask you if I could access the material of the course since it is indispensable for my activities at work".
- "I am thankful for the attention given, and I take the opportunity to congratulate you on the excellent organization of the classes".

The TELEDUC environment is a platform to the implementation of courses (subjects) over the Internet, aiming at the distance education, which has helped us on the connection with the students and on the disclosure and application of the didactic material, besides the attended classes. A master's degree work, which analyzes the students feelings concerning this tool as a didactic support on the teaching of Electrotechnics may be seen at Castilho, (2005)[2].

take experiments in easy way to communities with very low technology availability.

TABLE I

Number of visualizations (September/2009)

Didactic Videos	Number of visualizations
1. Voltage-Current Characteristic	951
2. Root Mean Square (RMS) Concept	2915
3. RC Series Circuit	27152
4. RL Series Circuit	4787
5. RLC Series Circuit	12081
6. Unbalanced Three-Phase WYE-connected Load	5232
7. Three-Phase Voltages	3237
8. Power Factor Correction	3736
9. Rotating Magnetic Field	5983
10. Simple Type Switch	1880
11. Three-way Switch	4058
12. Four-way Switch	2570
13. Residential Connections in the Electrical Network	878
14. DC Motor Starter	936
15. Starting of Induction Motor	817

V. THE SCHEMATIC DIAGRAM

A didactic video as well as a Virtual Laboratory project can attend several important requirements as cost reduction, easy handling, simulations and destructions in several learning sessions. From theoretical environment up to physical implementation, it is possible to specify some layers in a strategy to divide the design in levels and assure the laboratory usability, Fig 3.

All necessary parts to create a test environment with monitoring resources and a learning system can be seen in a core system layer. There are Input and Output devices to adjust appropriate income signals and to show the effects in alarms, displays or even a simple point to be measured.

In order to meet the speed, flexibility, portability and high quality demands, it is possible to use popular computer software and an efficient picture format as “FLASH” and vector images, respectively.

The path to the physical environment can be done through the local network or even using the Internet. Nevertheless the great contribution made by a didactic video is the possibility to

Fig.3 - Design and implementation layers

Other advantage is the possibility to transmit, reproduce several turns, stop and go in different moments and situations, not excluding the interaction with virtual laboratory and a physical implementation e validation, Fig 4.

Fig.4 – Virtual laboratory

VI. THE PARADIGM OF 3E

A despite of all educators efforts to improve the learning environment with news resources, creativity and new methodologies; they can face a new reality, Fig 5. The nowadays students, as the current workers, are not the same of few years ago. Besides the basic knowledge, the new student has to develop, in a school time frame, the “paradigm of 3E”, Fig 6. The academics have been discovering that there are much more behind the E from E-Learning expression besides Electronic.

The first “E” is about “Entrepreneur” skill, where his carrier and his personal investments depend on his proactive actions to collect its results in a short term. Not so long there was a time where a good school was enough to launch good students to prominent carriers, making to emerge amazing executives, lapidated by capitalism, in order to support the demand for human capital, one of its fundamentals.

Fig.5 - Basic knowledge compression

Increasingly its complementary training session has been moved to academic seasons, pushing students and educators to follow an additional agenda. It has created an even more robust curriculum, where good students become potential investors, handling a new theory that consider business and natural resources, as well as ROI (Return of Investments) and stocks, besides other commodities, financial indicators and management programs. This new procedures will transform potential undergraduate “baby juniors” in pre-warmed tires able to jump faster in a start line racing, reducing the time to market and accelerating the productivity. The main issue is the possible high social cost involved in this warm up procedure. The professional learning curve, when moved to academic season, can compromise the education and abbreviate the productive period for each professional life, against the original plan. Since there are confident suppliers for qualified human capital, the restructuring process has been anticipated and even more frequent in work world.

Fig.6 - The paradigm of 3E

The second “E”, from the “paradigm of 3E”, means “Entertainment”. There is no chance to handle stress, rush, the huge schedule and a competitive usual work environment without good humor and health. One alternative to develop this support comes from Entertainment. In academic season it means much more than a good life support, it means preparation for a social life, where the citizen building and the relationship skill will be mandatory for a well succeeded carrier. With direct impact in self-conscious and self-confident, the entertainment activities can improve the world vision, the general culture and the ability to handle different situations in personal and professional life. This is not a new concept but the issue comes from a new constraint created by a huge academic schedule responsible to accommodate new and complex procedures. The premature professionalization has pushed several new activities to academic season compromising the social life construction, extremely important for all moments of the citizen, the students and professional lives. As part of relationship program several university's programs include various classroom-specific programs where students in education courses receive diversity training as part of their teacher training, while students in the business school focus on understanding global cultural differences. There is no doubt about importance of diversity and social integration, in fact companies want to hire graduates who are prepared for the real world. Recruiters were once glad to discover that students understood the impact of diversity in the workplace, for instance.

The third “E” means “Expertise”. It is easy to understand and believe in the usual statement:

“Your value is in your unusual skills”

It can explain a well succeed soccer player makes more money than several competent PhDs. This point of view has generated a rally, one student competition to develop new skills as fluency in several languages, specialization, extra scientific tasks and foreign academic programs besides others activities.

Language training programs seems to be a wise idea, but how long do you take to learn Mandarin? Again, there is a time constraint to accommodate the language training with graduate season, for instance. To work in France, you need to learn French, and to work in other countries, such as the Netherlands, Singapore or China, you can get by on English for an extended amount of time. In Japan, your lack of cultural familiarity may prove even more challenging than not being able to read the road signs. There are skills that are more valuable in a global marketplace, like a language. Beyond language training, future workers who plan to tackle foreign assignments or whose work will require them to collaborate with customers, coworkers or suppliers in foreign place have to enroll in extra executive education courses.

From the point of view of curriculum analyses it certainly represents a positive wave, but there are at least two issues in the horizon:

- In a long term will not be differences between students, it will promote an academic qualification upgrade offering best professionals to companies, but for the same salary. Even if it means an achievement, there is a great chance to create damages in other fundamentals as basic knowledge or even school programs stimuli and retention ;

- There is no time to accommodate so many new tasks without compromise the basic knowledge for professional and personal lives.

VII. CONCLUSIONS

We have noted through this work that we can use amateur shooting equipments and software that is easy to handle, as it is in "Windows Movie Make" to produce great results, when dealing with didactic video production, and thus contributing to the improvement of the teaching and the knowledge propagation.

The videos answer a claim from the students to make easier the understanding of the electrotechnical theory, for it deals with the practical aspects, and this subject does not include laboratory classes.

The contribution to the teaching and learning process through the videos may be observed through an improvement on the students' performance at the evaluations, as in tests as in exercises available at the TELEDUC environment.

The knowledge disclosed this way is being useful to our students and to students from other teaching institutions, who may watch countless times, a specific concept on fundamental electricity. The videos and the way they are disclosed, bring up conditions so that the learning process happens in a more efficient and faster way, being available for a larger number of people, besides the students having the benefit of being able to watch the experiments when they have time, and be able to review the subject.

The formulation of didactic videos by teachers and/or students to disclose knowledge and to motivate learning is something that must be stimulated and encouraged.

A despite of well succeed initiatives to promote an even better E-Learning quality, there are so many changes to do in order to accommodate so many new tasks in students lives. It seems to be necessary to discuss a new curriculum, new assessments, new values and targets involving the academic institutions, the government, the corporations and society.

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Session 99 Non traditional papers

Model of Virtual Laboratory

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Higher Education Process Management Model, Educative Programs Improvement in Software Quality

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Virtual Laboratory for supporting chemistry learning and practicing

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Abstract—**This paper describes the importance of developing learning tools, such as virtual laboratories in different areas of science with emphasis in chemistry, through the development of a virtual laboratory that allows students to access to an environment of experiential learning. It has two main stages which are: a virtual world (software) where the student is guided by an integrated environment with the features necessary in order to perform the practices and at the same time, has a capture stage (hardware) that is responsible for making the process of experimentation as real as possible, offering the instrument's sensation or machine's sensation during the experiments. Throughout the document the steps for the completion of the virtual laboratory are seen with the results so far.**

Keywords-chemistry, distillation; virtual laboratory; virtual reality.

I. INTRODUCTION

Today the implementation of educational tools in interactive environments has allowed the acquisition of knowledge, it presents an innovative and efficient way to learn and teach giving the opportunity for students to access experimentation in an almost real manner, allowing their full learning which is not dependent on specific artifacts and materials but on accessing to the virtual laboratory.

Nowadays, there is an increasing popularity in virtual laboratory environment for its prominent advantages of intuition and interactivity between teaching and studying [1]. Interactive tools accompanied by modern educational theories configure a tool that currently has a very important impact in students of all areas of science and technology and has a main role in the current educational process.

The objective of the virtual laboratory proposed in this paper is to create a laboratory environment which motivates students to discover connections between theory, simulation, and physical systems through independent experimentation with up-to-date professional tools. [2]

The implementation of information and communication technologies has developed different types of virtual laboratories, in this case is being developed a virtual laboratory which has a virtual world that allows the immersion in an environment conducive to practical implementation of distillation in chemistry field, along with an electronic device specifically a virtual reality glove that has the function to capture the movements and position of the student's hands, and thus making the practice very close to reality and generating a theoretical and practical learning.

Although theoretical concepts are essential and need to be taught, it is very important to also show students how to apply the theory they have learnt in very different and important practical situations. [3] In some areas of knowledge the apprenticeship is not complete until you have developed different practical activities, so an example of this case is the chemistry field. Many subjects are based on it (practicing and experimenting), especially subjects which have more practicalness, such as: programming, physics, chemistry, and other engineering subjects. [4]

Besides the development of such interactive tools is necessary to promote a new culture in the learning process, since there must be a motivation with students who are interested in using tools and devices built for intellectual growth, is necessary to discard traditional pedagogy that leaves very little scope to the student and instead propose a constructivist pedagogy which guides the student to identify and define the problem, the proposal procedures, collection and interpretation of results and making decisions. [5]

Besides, virtual laboratory can also benefit distance education and learning-on-the-job students, who maybe asynchronous in time or in space, even more, for the cost and time needed for traveling to a local lab would often prevent them from using such real laboratories. Moreover, the virtual laboratory resources can be shared by many institutions and students worldwide, which can save much money. [6] There are many applications and advantages of virtual laboratories as their implementation in distance education or the acquisition and management of expensive tools and machinery that is not easily acquired.

Therefore, the main research question to be solved is: How to develop a virtual laboratory of basic distillation that can be handled from an electronic device (virtual reality's glove), to support the teaching process of distillation? From the previous question and development experience of the research group in this type of tool, the following questions arise also be solved with the investigation: How to design and develop a motion capture device that allows sense signals generated by a hand movement? And how to design and develop a three-dimensional interface that allows displaying the manipulation of objects in a basic distillation laboratory from a remote hand and support the teaching process distillation?

II. Virtual Laboratories

A. History Background

Due to the need for student support systems to make their laboratory practices, with the aim of optimizing time and resources required in a controlled environment to provide security, the advancement of new technologies of information and communication and adoption of recent educational and pedagogical practices, emerged virtual labs as a support for the process of student learning.

The approach now in education, where new spaces are built and troubleshooting, virtual laboratories, have gone deep into the pedagogical practices, for over 25 years or so, when its use began. The first approach to virtual laboratories appears in 1984, where the concept of virtual instrument and its characteristics were determined according to the fundamentals of programming. [7]

In 1992, virtual laboratories described the object-oriented programming in the development of a laboratory simulation. In 1994 was presented a study by Vanderbilt University in the U.S. which develops a simulation-based virtual laboratory to support traditional practices, which concluded with the need for this tool to learn basic skills and equipment management, which optimizes both the time of pupils as the laboratory staff, in 1994 was written an article [8] in which is explicitly defined a virtual laboratory as a simulation program.

Already in the IMTC conference (IEEE Instrumentation and Measurement Technology Conference) held in June 1996, started to present different aspects of what is a virtual laboratory.

B. Concept

A Virtual Laboratory is an interactive virtual space that incorporates all the technological, pedagogic and human resources in order to perform practical activities, adapted to the student's and teacher's needs in a virtual learning environment [9].

The virtual laboratory is composed by a virtual world which is based on the required pedagogy by the area of science where it is implemented and the development of the virtual environment to make it comfortable and real to the student. Along with a hardware tool which is an essential resource for learning as it provides comprehensive real sense of the object that is being manipulated within the virtual laboratory.

In addition the laboratory should have the following Characterisitcs says Vikram Padman and Nasir Memon [3] Accessibility, Observability, Ability to simulate realistic scenarios, Realistic, Separability of virtual network, Remote Configurability, Ability to share resources efficiently. With accessibility it is understood that a student can easily access the virtual laboratory and its elements, the Observability characteristic is about the possibility of students to observe the effects of their actions within the virtual laboratory, as it would be in reality.

The ability to simulate realistic scenarios, where realistic, mean that the virtual laboratory should have an environment that gives a real sensation of the practice. The separability of virtual network, Remote configurability and Ability to share resources efficiently are Referred to the capability of the virtual laboratory to allow interacting with it by many students at the same time, without generating problems in the virtual environment also the virtual laboratory should permits to be modified at any time by the laboratory's administrator.

C. Importance

Despite distance education acquires some results in theory teaching, the expansion of the experiment manipulation teach has become the main factor which restricts the further development of distance education. [4]

The importance of virtual laboratories can be seen in distance education as these allow students to access information from different places, it is not necessary for them to be at the same school or even in the same location.

Engineering students need to practice and perform experiments in laboratories in order to complement their learning process. However, instructors and equipment are not always available. Additionally, there may be risk and trouble using some equipment that may hurt students or damage the equipment. [10]

In these cases the use of virtual labs is the best option for engineering students where is needed to use equipment that do not have or it use is dangerous for the student. Thus, it appears that some of the main reasons for using these tool: the decrease in investment in expensive machines, the expansion in the restricted access to expensive laboratory equipment and, the limited availability of free time in laboratories for new practices to enhance knowledge on a specific issue and reducing the cost of consumable items.

III. Chemistry Virtual Laboratory

The virtual laboratory was designed and is under development to support the teaching of chemistry distillation consists of three basic components: an interaction device (suits, gloves, helmet or other component that allows movement user), a motion capture device (electronic device that receives signals (movement) of the user and transmits to the computer) and a software interface (virtual world) that contains a three-dimensional scene with real-world elements simulated, which is operated with the signals received from the motion capture device. Additionally, the software interface (virtual world) incorporates in its operation a teaching model and didactic to facilitate the learning process.

The interaction device consists of a virtual reality glove which senses movements of the student's hand capturing the different activities that can do in the distillation process in the virtual laboratory implementing low-cost sensors that make the glove more accessible to all users. The motion capture device is responsible for capturing the different signals from the virtual reality glove to identify and order it with reference to the voltage found on the analog inputs of a microcontroller and then feedback a response to the virtual world of the computer where it generates a real-time response to the action performed by the student.

The software interface (virtual world), includes the basic elements of a laboratory distillation within a scenario of three dimensions, which are handled according to data supplied by the motion capture device. The interface is being developed with software for virtual worlds building in third dimension (such as VRML, X3D and Blender), signal capture programs, programs with special procedures and intelligent agents (developed in Java programming language), enabling to provide an interactive environment for users. Additionally, the interface has a constructivist approach and a learning component based on the resolution of problems, some examples are showed in table 1.

TABLE I. EXAMPLES OF SOME VIRTUAL LABORATORIES

Virtual Laboratory's name	Authors
Vital (virtual Information assurance laboratory)	Vikram Padman and Nasir Memon [3]
Virtual laboratory for signals And systems	Virginia L. Stonick [2]
Simulated lathe virtual laboratory (LaSiTo)	Julieta Noguez, Gilberto Huesca [10]
UVL (universal virtual laboratory)	Michael Duarte, Brian P. Butz , Susan M. Miller, and Annapoorna Mahalingam [19]
The Robotics and Computer Vision Virtual Laboratory	Lucian Rodrigues de Queiroz, Marcel Bergerman, Rubens Campos Machado, Samuel Siqueira Bueno, Albert Elfes [20]
VnLab (virtual networking laboratory)	Josep Prieto-Blázquez, Joan Arnedo-Moreno, and Jordi Herrera-Joancomartí [9]

IV. METHODOLOGY

The development of the project involves a combination of several methodologies: one for the development of the research process Table 2, one for an interaction device (virtual reality glove) Table 3, another to do the motion capture device Table 4, one for the design and development of a software interface that reflects a virtual world of a basic distillation laboratory supported in the teaching model of problem solving Table 5.

Initially defined and explained in Table 2, the research process that will be followed from the research process models proposed by Morgan silver [11], Lerma [12], Tamayo [13] and Cerda [14].

TABLE II. RESEARCH METHODOLOGY

Stages	Description
Defining the topic	During this stage, it was clearly defined and precisely the work area or field of research problem.
Indentifying the problem	During this stage, it was specified in detail and precisely the problem. Defining the limits of the research.
Defining Objectives	During this stage, the objectives were defined taking into account the actual results, scope and results.
Definition of Justification	During this stage, it was defined the motivations that led to the development of the project.
Development framework	During this stage, we took into account the previously constructed knowledge, which is part of the existing theoretical structure and experiences in the world.
Definition of the methodology	The investigation was developed in three phases, the first consist of the construction of interaction device (Virtual Reality glove). In the second phase, was built the motion capture device. In the third phase, there was the software interface that contains the virtual world of basic laboratory distillation.

The development of interaction device (Virtual Reality glove) was done following the steps described in Table 3.

TABLE III. INTERACTION DEVICE METHODOLOGY

Stages	Description
Planning and organization	At this stage is defined what will be done, the list of activities, team work, artefacts that constitute the device and the required tools.
Requirements	At this stage is setting out the different characteristics that the device must have
Analysis	At this stage, is analyzed the requirements set at the previous stage and build a model to define which are the components of the device and how they operate, determining the physical structure and technology used.
Devices design	At this stage, are made the sketches, proposals for structural design and performance, overall design of the glove, transducers design
Development and construction	At this stage, is made the glove implementation, the sensors, signal conditioning and signal transmission
Tests	At this stage, individual tests are performed and capture device.

The motion capture device is done following the steps defined in Table 4.

TABLE IV. CAPTURE DEVICE METHODOLOGY

Stages	Description
Requirements	At this stage is defined the requirements of motion capture device taking seeing the requirements and system software in general.
Analysis	Taking into account the requirements, the devices are designed as well as their characteristics
Design	Design and simulation of the capture system.
Implementation	Performing the installation of the device.
Tests	Adaptation and testing of signal acquisition

The methodology for the design and development of the software interface that contains the virtual world of a basic distillation laboratory will follow the RUP methodology from the models Jacobson, I., Booch, G. and Rumbaugh [15], Weitzenfeld [16] Scharch [17] and [18].

TABLE V. VIRTUAL WORLD METHODOLOGY

Stages	Description
Business Modeling	At this stage is identified the main processes that will be performed in the laboratory, will make the process diagrams, domain model and a glossary of terms.
Requirements	At this stage is defined the virtual laboratory requirements for which were made the initial list of use cases, the clearance of these, their model and documentation of each use case.
Analysis	At this stage is defined the conceptual view of the virtual laboratory, for which it was done, sequence diagrams, collaboration and activity for each use case, the state diagram and model analysis.
Design	At this stage is defined the programming vision of the virtual laboratory for which shall be carried out CRC tables to establish the responsibilities of the objects, the interface model, the logical model, physical model and data dictionary.
Implementation	At this stage the schedule is made of the various systems that comprise the virtual laboratory, which will be made for the deployment diagrams, packages and components and the code of each of the subsystems.
Tests	At this stage the tests are conducted and system integration of each of the systems comprising the virtual laboratory

V. RESULTS

The developments achieved in the project, offer opportunities to acquire knowledge for the deployment of new virtual labs, creating virtual worlds, design and development of motion capture devices based on wireless sensors and cameras, as well deploying applications as telepresence, which can be used generically to build solutions in education, health, entertainment, industrial, etc.

The project helped to identify mechanisms to incorporate the teaching model of problem solving within the operation of the virtual world, which has facilitated the use by students of the device.

The construction of the laboratory includes the formation of a task force comprised of people from different professions (system engineers, electrical engineers, designers, educators, teachers and students of the subject of chemistry), who have worked in an organized and have allowed the approach new projects, seen from different perspectives.

VI. DISCUSSION

The design and development of virtual laboratories oriented to education should consider incorporating educational and teaching models, because it facilitates the use and student motivation to perform the various practices in the laboratory.

The practices that students will perform in the virtual laboratory, must be integrated with the programming being done by the class teacher, as this allows better results in the transfer of the different concepts.

The development team of a virtual laboratory oriented to education must have professionals from different areas such as systems engineers, electrical engineers, designers, educators and experts in the field that allows the construction of the laboratory from different perspectives.

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Process Management Model for Higher Education

Improvement of Educational Programs in Software Quality

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Abstract— **This paper presents a Processes Management Model for Higher Education (PMMHE) characterization. With the PMMHE is possible to produce a comparative measurement system (benchmarking) of organizational, tactical, logistical and operational processes for formation, training and coaching programs in higher education institutions. The current PMMHE's release has impact on engineering programs and emerges as a strategy of the Colombian Government in its effort to articulate the university and industry, particularly the software industry and education of software engineering and their related areas at technical, technological and professional levels. The model is defined as knowledge management tool, which provides a scenario of variables and requirements classified by process categories and areas, practices, resources and products of processes, in which the institutions can to develop assessment practices to exchange resources, knowledge assets and best practices. This scenario is seeking to promote the establishment of a process improvement environment in higher education programs of engineering. It is very important to emphasize that the model's strategy is the transition from the subjective to the objective, for obtaining impact and spread and internalization knowledge, beyond the mission statement of institutions. This derivation from hypotheses to the thesis supported in facts, leads the formal use of statistical process control for knowledge management which includes the measurement systems analysis and collect measures about teaching - learning collective and individual processes under constantly balancing between the theory and the practice about the scientific and professional aspect. Also, this paper presents the lessons learned and the assessment for applying the model to 58 companies and 5 institutions of higher education related with the software industry in Colombia.**

Keywords- Process Maturity Model in Higher Education; Measure Systems for Higher Education, Knowledge Management in Higher Education.

I. Introduction

In the last 10 years, one of our lines of research work has been the development of quality management systems applied in higher education. The focus of our research is the several adaptations of software engineering's innovation frameworks [3], particularly, CMMI, ITIL, PMI, SWBOK, SPICE and ISO (12207-20000-15504...).

Due that academic community at university-level in Colombia are using information and communications technologies (ICT's) in their certification processes for their higher education programs, in great part achieved with our work, currently our actions are pursuing in way of get that the higher education institutions are developing strategies to formalize processes for management, authoring, instruction and assessment of the university programs offered in Colombia.

The document is divided into seven sections. In the first part, we establish introduction and organization of this paper.

In the second part, we provide an overview of the process and competences paradigms that allow defining the different kinds of educational processes. This way, the educative programs appears with organizational, primary, support and adaptive processes. Additionally, we present an overview of the three different studies that support the model proposed: Academic and Administrative Management of Educative Institutions, Quality Assurance System for Higher Education and Software Quality Colombian Network. Finally we establish the research problem we are trying to solve the model and the applications discussed in this paper.

In the third part, we propose that, if the educational programs are in crisis, a paradigmatic change as a discipline is required and we propose the management by processes support in competences for that change. In addition, based on maturity models arguments, we assume that all paradigmatic change can only be possible adopting a critical attitude and then promoting a new paradigm. This part ends with describing the specifications and architecture of the Academicals Programs Framework: Knowledge assets management; Authoring, Development and Maintenance; and, Instruction, Certification and Professional practice.

In the fourth part, we exemplified by a studies case of on how it is adapting the PMMHE framework in training non-formal programs in state institutions and undergraduate and graduate programs in various universities in Colombia. In addition, we reflect briefly on the scope and utility of this framework as benchmarking tool. The application of PMMHE demonstrates that the software paradigms are adaptable in different environments

In the fifth part, we explore the future trends we consider promising for research in the short term: Higher Education Accreditation and Assessment, Personal competences certification and Peers School.

Finally, in the sixth and seventh parts, we present the Conclusions, Acknowledgments and References of the paper.

II. BACKGROUND

A. Relationship beetween Process and Competences Models.

Processes are generally defined as "a set of interdependent tasks transforming input elements into products" [1]. A process generally comprises the following elements [2]: a purpose; the responsibilities of the participants in the process and their duties; the entrance criteria for the elements or conditions needed to begin the process; the inputs (artifacts, information or material) needed to perform the process; the activities, tasks or actions which make up the process; the outputs (artifacts or assets) that result from produced or modified by the process; the exit criteria (elements or conditions) needed for process completion; the process measures that support the process performances or future performances; tools, techniques and knowledge used in enactment the process; the adaptation patterns for tailoring the process in several contexts; the interfaces with others processes; and, records of information to future use.

We have [4] renamed (Fig. 1) the inputs and outputs as input resources, process and product. The input resources may be of use, consumption or transformation. The output resources include products and information. Use resources are used as service functions to the process. The consumer resources are materials that will be consumed during the process. The service functions are performed by roles and each role has competence units (CU) and each CU is associated with the activities of the process. A process can be atomic or compound. The atomic process consists of tasks of direction (leading and management), support, primary and adaptation (instantiation through planning and performance). A composite process consists of sub-processes that can also turn are direction, support, primary and adaptation processes. The politics of the processes includes the objectives and the business rules for each resource category. The scope, knowledge and quality of the process and its products, is seen around all types of resources and is established through the functional and nonfunctional requirement [5] that define them.

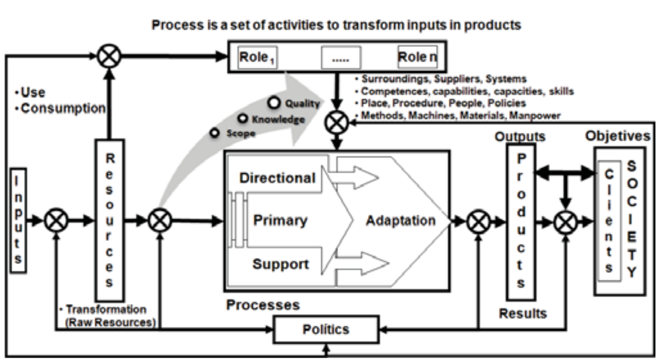


Figure 1. Process Model [4]

A special role belongs to human resources when they are assigned and are responsible for the implementation of relevant activities of the processes. In our work, the role is associated with the units of competence, which are closely linked to the people performance in the processes. This fact raises the competences assigned to the roles of individuals are vital and interdependent with the processes.

B. Academic and Administrative Management of Educative Institutions

In order to establish a collaborative (all for one) and cooperative (one for all) network was conceived the GAYA Project [6] (Fig. 2) as Colombian educative sector unit. This unit was appreciated as a system supported in new telecommunication technologies and different educative agents (entities, government and communities). This unit was developed to model, share, deploy, monitor and make consensus in the different knowledge associated with the educational processes, mainly in aspects as to make and to establish the insurance and model politicians of quality processes about configuration and requirements of inputs, resources and products and/or services.

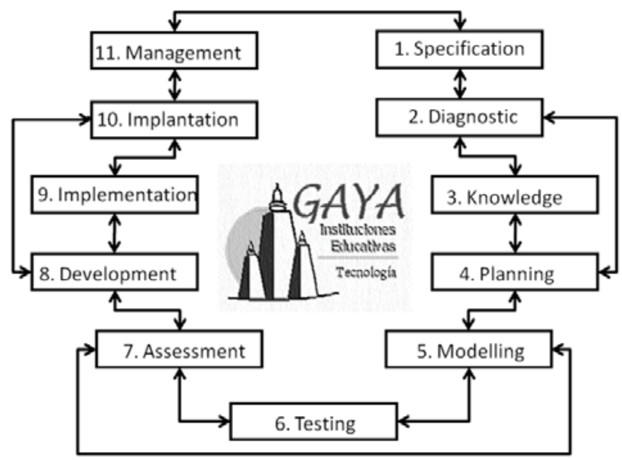


Figure 2. GAYA Model [5]

GAYA is a process to develop an educational institution in five levels:

1. Recognized State: An educational program is in a recognized state when indirect communications features or inadequate, quality management and process implementation limited and inconsistent relationship with users and providers. Processes are ad hoc and even chaotic. Few processes are defined and success depends on individual effort.

2. Normal State: An educational program is in a normal state if it has basic processes to track costs, plans, programs, agendas and functionality. The discipline in this state repeats early successes processes in similar applications.

3. Formal State: An educational program is in a formal state of formalization, whether the activities and administration are documented and integrated as standard processes in the school. Thus, institutional

activities, is developed and maintained, usually using approved procedures.

4. Managed State: An educational program is in a managed state when there are standard measurements about features about resources. Thus, the processes are quantitatively and qualitatively understood and controlled.
5. Optimized state: An educational program is in a sate optimized, when it makes continuous improvement through quantitative feedback, valued in the process.

The processes carried out to climb each of the levels are summarized in the Table I and fig. 2.

TABLE I. PROCESS TO GO THROUGH THE GAYA´S LEVELS

Process	Description
1. Implantation	Identification of needs for determination processes of development
2. Diagnostic	Establishing criteria for selecting organizational entities to model and training needs assessment and knowledge of human resources in the process.
3. Knowledge	Determining organizational entities candidates, for selecting the organizational entity and human resource development will intervene in the process that will be modelled.
4.Planning	Planning scope, policies, objectives, activities and resources required to implement the process on the selected organizational entity in Phase 3.
5. Modellling	Development of an organizational entity modeling pilot using the software.
6. Testing	Simulation or execution of pilot.
7. Assessment	Evaluation of pilot test, which decides whether to continue with step 8 and repeat the steps 5, 6 and 7.
8. Development	Scheduling and resource allocation for mounting the organizational entity modeled, tested and validated in stages 5, 6 and 7.
9. Implementation	Implementation of the organizational entity according to the programming stage 8.
10. Implantation	Training and Installation of the organizational entity produced in step 9.
11. Management	Administration and Organizational use of the entity-mounted stage 10.

Through the GAYA project was possible to establish the need to define and establish a quality management system for the higher education institutions. This need was referred to the National Education Ministry of Colombia when we presented the results of the pilot project about five Colombian universities. The event was the beginning of a new project: Quality Assurance System of Higher Education (In Spanish "Sistema de Aseguramiento de Calidad para la Educación Superior" – SACES -. SACES is described in the next section.

C. Quality Assurance System for Higher Education (SACES)

This project created the SACES System for Colombian Higher Education Institutions (HEI) [7] automatically perform the steps associated with the registration and qualified institutional type processes as: Legal personality recognition, Approval of feasibility study for public higher education institutions, Institutional character change, Recognition as a university, Redefinition for offering preparatory courses and Authorization for creation of institutions. With this process-driven system the presidents of educational institutions can apply the qualified and track record in each of the stages and requirements: Filing, Assignment of pairs, pairs Visit, Evaluation, and Resolution Rules.

The SACES (Fig. 3) is the first process management system that has the Colombian National Education Ministry that manages roles and responsibilities within the process. Specifically, the system has the following processes which are pre-defined roles (Table II) and on which it is possible to establish performance statistics and process and product quality.

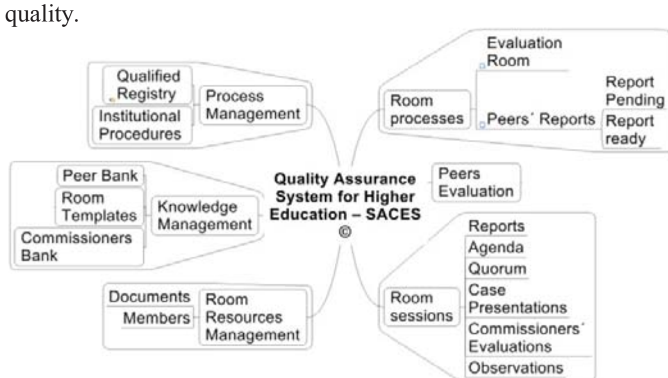


Figure 3. SACES [7]

TABLE II. PROCESSES AND ROLES IN THE SACES

Process	Roles
Process Management • Qualify Registry • Institutional Procedures	Presidents of Institutions System Manager Leader Manager Legal Operator Verifier Operator
Knowledge Management • Peer Bank • Room Templates • Commissioner Bank	Room Secretaries System Manager Leader Manager Verifier Operator Academic Peers Academic Commissioners
Room resources Management • Documents • Members	Presidents of Institutions Room Secretaries System Manager Leader Manager Legal Operator Verifier Operator Academic Peers Commissioners
Room Sesions • Evalution Reports • Commissioner Reports • Peers Reports • Validatios	Room Secretaries Academic Commissioners

Although SACES processes are ISO9000 certified and who use the system do it like a social network, the owners and users have identified the need to formalize the competences to enhance and certify the performance of those using the system. One of the actions to undertake in the short term is the creation of the peer's school to improve verification visits to the institutions.

SACES operates within the legal framework that is supported and verified by academics peer institutions to meet the quality legal requirements. Such conditions are classified as program and institutional Terms.

The program quality terms are: Correspondence between the name of the program, curriculum content and achievement of goals; adequate reason for existence of the academic program; a curriculum; Activities that strengthen academic knowledge; Adequate training in research; The proper relationship with the external sector; Number and quality of teaching personnel; Educational media for teaching; Physical infrastructure in classrooms, libraries, auditoriums, laboratories and spaces for recreation and culture.

The Institutional terms are: Selection and evaluation of students and teachers; Existence of a formal administrative and flexible structure; Self-assessment culture; Graduate program; Institutional Welfare in health, culture, living, recreation and economic and labor conditions; Adequate resources to ensure compliance with quality goals, welfare and ability to project into the future, according to the needs of the region and country.

SACES system as a whole that detects weaknesses around the terms of quality though failing to analyze the processes and resources (including the skills of those involved), thus, the institutions do not yet demonstrate the quality of its processes and one notes the need to go down to the process performance and quality of results to truly determine the quality requirements at all levels.

D. Software Quality Colombian Network

The Colombian Network of software quality (RCCS) [8] (fig, 4) is a knowledge management tool based on an engineering model, which seeks to strengthen the national software industry and related services supported in software quality standards and international specifications.

The RCCS has been designed in response to the call of SENA and COLCIENCIAS to Support the Strengthening of National Capabilities in Software Quality, as an area model to facilitate the collective construction of knowledge part of the various agents involved, with the initial purpose of facilitating the process of implementing CMMI [9], adapted to the culture and national context.

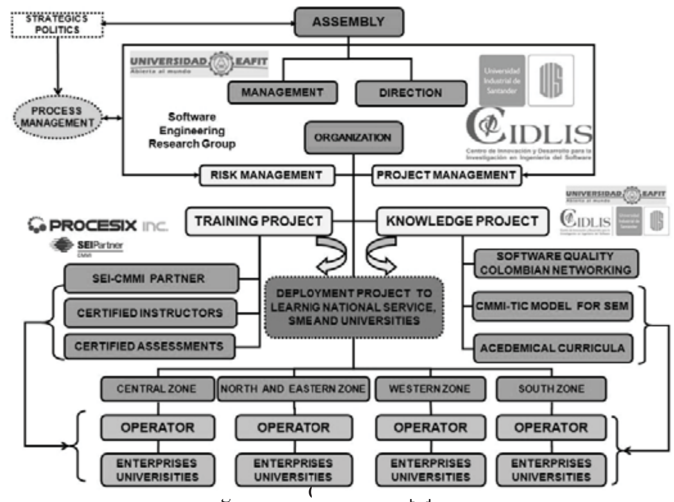
The country has been divided into four geographical areas: North-East Zone, South-West Zone, Center Zone and Coffee Zone.

RCCS network has as main objectives:

- Define and manage programs to support the implementation of software quality models for Small and Medium Enterprises (SMEs) in the sector nationally.
- Develop research projects and methodologies applied in quality models for industry and others who meet the purpose of strengthening the domestic software industry.

RCCS is developing seven sub-projects to achieve its objectives:

1. Creation and implementation of RCCS
2. Training and Certification of CMMI leader appraisals.
3. Training and Certification of CMMI instructors.
4. Implementation the CMMI model in software SMEs
5. CMMI initial assessment of software SMEs
6. Development of a model of Software quality for SMEs
7. Educational programs improvement in software quality



The training and education activities related to this paper are defined in sub-projects 4, 6 and 7. In the sub-project 4 met the needs of education and training demanded by SMEs. In the sub-project 6 was determined the process model. And, in the sub-project 7 will be defined improvements to educational processes in software quality.

The processes established to improve educational programs are (Fig. 11): Process management (improvement, definition and training), Project Management (planning, monitoring and control), support (decision making, asset management, measurement and quality assurance).

The development of sub-project 7 has served as a benchmark to create an approach to integrate the results of GAYA y SACES projects, provided a way to integrate the academic and management processes of academic institutions regarding the management, the authoring and the instruction related to the competences model and academic degrees.

E. Issues, Controversies, Problems

Considering the problem as the difference between a desired state and current state, now we summarized the problems set out from the issues, controversies, scenarios and results achieved in the projects described in the preceding paragraphs.

Some of findings encountered in our observations are as follows:

1. The various stages (fig. 10) involved in the process of teaching - learning of basic education, professional basic education and applied engineering professional Education in engineering education programs are not fully formulated and are delivered as if they were

independent and this fact causes weaknesses when graduates seek to integrate the workforce.
2. Most Universities do not develop training activities for the integration of graduates from academic programs to the productive sector, thus, there are delays in their incorporation into the workforce.
3. In the case of information technology and communications, the universities do not distinguish between educational programs in science and engineering; for example, do not differentiate between academic programs in computer science and software engineering.
4. Many Universities are more concerned about the financial benefits that the results of the professional performance of graduates.
5. Higher educational institutions do not manage the knowledge and the competences of the processes associated with the educational program management.
6. There is not benchmarking models of processes in the higher educational institutions without which it is difficult to define policies for the processes improvement because without such studies cannot establish the best practices of learning and educational management in Colombia.
7. The curriculums are made without contextualizing with the reality because they are not integrated into the current social processes.
8. The Colombian educational objectives are process-oriented to integral formation but this is not aligned with these objectives because to do so would require competences-based curricula because the competences are directly relationship with the processes.
9. Although some international approaches to develop and adapt competency-based curricula have been transferred to our environment such approaches are not fully understood and properly adapted because there are no techniques to define maturity levels of learning - teaching proven strategies in order to adapt our environment and there is no effective, clear and practical methodology to develop and manage competences-based curricula.
10. The community is not prepared to appropriate formation, leading, coaching and teaching with competency-based curricula.

III. HIGHER EDUCATION PROCESSES MODEL

From the background now we will try our framework for our Processes Management Model for Higher Education (PMMHE). PMMHE is the product of the software educative programs improvement sub-project (Objective 7 of RCCS project). PMMHE has as principles, the top management structures developed with the GAYA [6] and SACES [7] projects to establish the basis for designing the teaching-learning processes to treat the primary process of formation.

The Education in this project has the perspective of the process approach, also called project-based learning or problem-based learning (PBL), which induces competences-based learning.

A. Competences-Based Learninig (CBL).

Now explain briefly CBL, defining its parts and some examples (Table III) and Figures 5 and 6.

TABLE III. CBL COMPONENTS

Parts	Description
Role or degree	An academic program which is composed of several competence units. For example (Fig. 7): Patron, Waiter, Cook and Cahier Roles
Competence Units	Each of the areas of process that plays a role. For example, support, planning, development of the work of cooking, cooking management processes for the example in Fig. 7
Competence Unit Assessment	Overall rating being made to all units of competence about perfomance and product and process quality.
Competence Elements	Each of the practices that a place within a competence unit.
Perfomance Criteria	Each of the sub-practices that a place within a competence element.
Evidence required	Each of the Work Product produced in a sub-practice
Essential Knowledges	All knowledhges units to run a sub-practice.
Knowledge units(Fig. 6)	Each is composed of the doing core, and the assesment unit and the the body of knowledge. For example; Fry potatoes. Demands to know about potatoes, how they are fried, and how it does the quality test of process and product.
Assessment units	Overall rating being made to the doing core using the Analyssis Unit and Synthesis Unit.
Analysis Units	Lets break down all parts in order to do performance and quality assessment.
Synthesis Units	Allows synthesis concepts in order to do performance and quality assessment.
Doing Core	Each is composed of the being core, the knowledge core and the assesment core.
Being Core	Each is composed of the phisical core and mental core charactristics of the person.
Knowledge Core	It is the basic knowledge of the a person.
Phisical Core Characteristics	Appearance of a human body.
Mental Core Characteristics	Psychological aspect of a human.
Analysis Core Characteristics	Key analytical aspect of a human.
Synthesis Core Characteristics	Key synthetical aspect of a human.

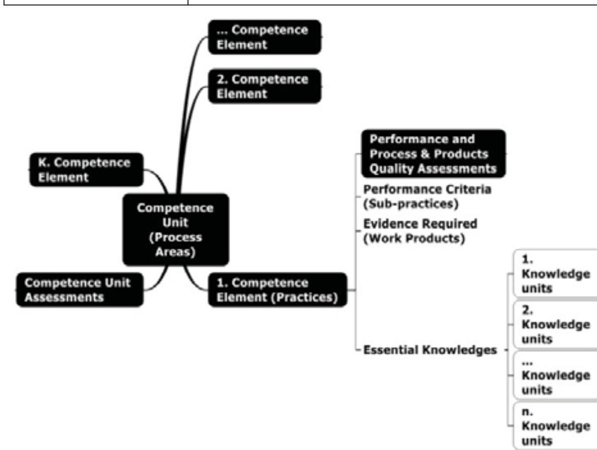


Figure 5. Competence Unit

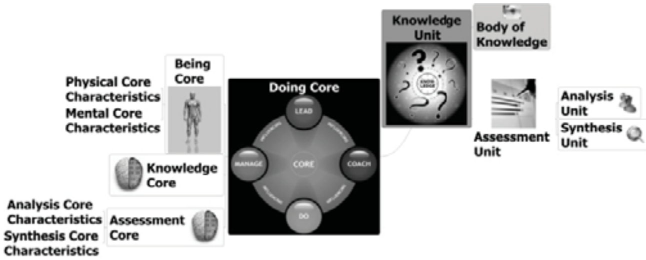


Figure 6. Knowledge Unit

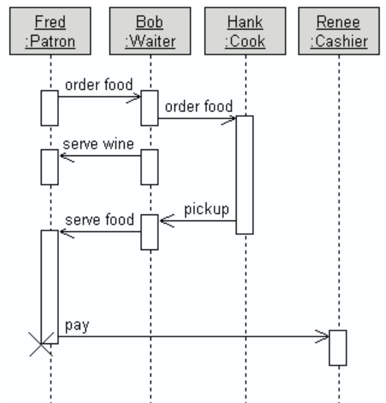


Figure 7. Restaurant Service Process [16]

The process of competency-based education is structured around a process as is the case for example (Fig. 7) where the process is the restaurant service, and each of the roles would trivially, to develop educational qualifications. This teaching-learning process requires teamwork, mentors, special educational materials, instructors, resources, managers for the teaching process, records of evidence, assessments, among others.

B. Description of PMMHE.

Such components are shown in the abstraction that represents "MANAGEMENT AND DIRECTION" in the upper block of the architecture model (fig. 8). The components that emerge in this structure correspond to three processes: Academicals Programs Assets Management (Knowledge assets management); Authoring Process (Authoring, Development and Maintenance); and, Instruction Process (Instruction, Certification and Professional practice).

1) The Knowledge Asset Management Process (KAMP).

The KAMP follows the guidelines established for project GAYA to improve academicals programs and manage baselines during the development or use of the academicals programs.

2) Authoring Process (AP)

The AP is designed to make the processes of academic program development under the vision of processes competency-based formation using project management as a support tool to develop an engineering process with:

- Specifications to support an academic program with units of competence, elements of competence, performance criteria (activities of a process), knowledge, applications and the establishment of evidence required to certify the skills acquired.
- Design to produce teaching-learning develop knowledge assets (learning objects) that are seen as technological applications which consist of reusable software components supported by software and hardware system and human resources
- Verification, Validation and Integration of components.
- Develop a comprehensive improvement process for resources, content, practices and the same authoring.

AP also includes development and maintenance processes to manage, maintain and update knowledge of authoring, to make them consistent, permanent and relevant to the learning process.

3) Instruction Process (IP)

The instruction process [11] is established following learning sequences through teamwork activities to solve problems through projects. The projects are supported by a tutor, a coach and several assistants, who are charged with overseeing all activities of the students. Tutors, coaches and assistants must be certified in the training process before offering academic education programs.

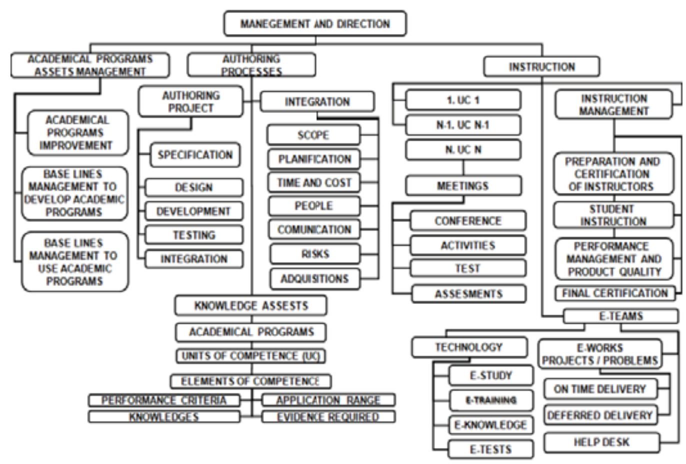


Figure 8. PMMHE [8]

IP may include certification procedures and, eventually, be linked to occupation; a fact that makes feasible the continuous monitoring practices of certified human resources and allows continuous improvement process directly into jobs.

C. Curriculum development methodology for competency-based educational programs

The methodology PMMHE combines the steps of GAYA methodology [6] with the steps of the Educational Software Engineering methodology [17] and has 11 stages (Fig. 9). The structure of the methodology combines project management with an adaptation of the software development life cycle. The structure includes the possibility of having the bodies of knowledge (for example, the Software Body of Knowledge) or the construction of bodies of Knowledge from processes in situ or from experimental prototyping construction processes. The bodies of knowledge should be associated with functional decomposition as specified in UML sequence diagrams [18] in which every lifeline represents a role type with its performance criteria (practices that can be executed).

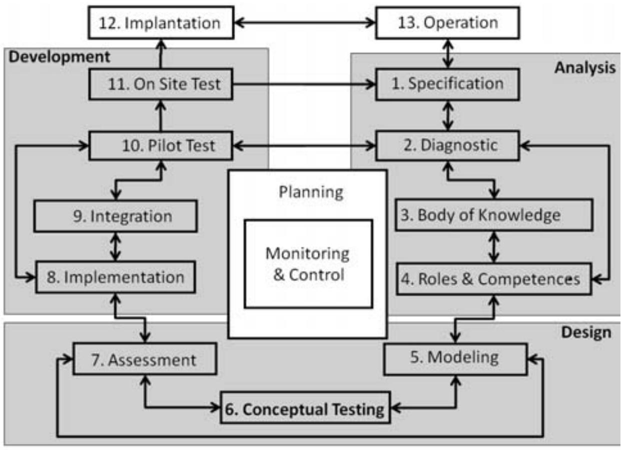


Figure 9. PMMHE [6]

It is absolutely indispensable that the programs have information and communication technologies for development of all activities.

The model is an adaptation of the CMMI models [9] [10] [11] [12] [13] [14] for development, acquisitions and services. The relationship is shown in Table IV where authorship associated with development, management and acquisitions services. It should be noted that the acronyms mean: The Asset management of academics program process (KAMP), Authoring Process (AP) and Instruction Process (IP).

D. Benchmarking from PMMHE

One consequence of the adaptation and comparison of PMMHE with the CMMI constellations is that the CMMI tools can be adapt to develop benchmarks for comparative measurements around the Process areas and roles. From this perspective, also, we can infer that it possible adapt the CMMI assessment methods [14] to solve the second problem that emerged in paragraph II.E. The assessment process can be done at individual or organizational unit using the measuring process of RCCS [8].

IV. PMMHE Prototype

Currently, we are verifying and validating PMMHE through curriculum development environment for software engineering. To determine which curriculum to mediate, we established the followings criteria:

1. Find the more difficult process of assimilation by the companies participating in the project RCCS.
2. Developing a competency-based academic program that would not affect the autonomy of educational institutions and instead enhance its programs.
3. Establish affinity groups to the perspective of the issues set out in the paragraph II.E.

The chosen program associated with project management and included aspects of process management, engineering and support (Fig, 10). The validation project was called " Improvement of Educational Programs in Software Quality”, in Spanish: "Mejora de Programas Educativos en Calidad de Software -MPECS"

TABLE IV. Processes CMMI and Competences in PMMHE

Constellation	Categories	Process Areas	R[1]
Common for all Constellations	**Process Management**	**Organizational Innovation & Deployment**	**All**
		Organizational Process Performance	**All**
		Organizational Training	**All**
		Organizational Process Focus	**All**
		Organizational Process Definition	**All**
	Project Management	**Project Planning**	**All**
		Project Monitoring and Control	**All**
		Risk Management	**All**
		Quality Project Management	**All**
		Integrated Project Management	**All**
		Requirement Management	**All**
	Support	**Process & Product Quality Assurance**	**All**
		Configuration Management	**All**
		Measurement & Analysis	**All**
		Decision Analysis & Resolution	**All**
		Causal Analysis & Resolution	**All**
Adquisitions	Adquisitions and Delivery	Agreement Management	KAMP
		Adquisition Requirement Development	KAMP
		Solicitation & Supplier Agreement Development	KAMP
		Adquisition Validation	KAMP
		Adquisition Verification	KAMP
		Adquisition Technical Management	KAMP
Development	Engineering	Requirement Definition	AP
		Requirement Management	AP
		Technical Solution	AP
		Product Integration	AP
		Verification	AP
		Validation	AP
Services	Process Management	Organizational Services Management	IP
	Project Management	Service Continuity	IP
		Supplier Agreement Management	IP
		Capability & Availability Management	IP
	Service Establishiment and Delivery	Service Delivery	IP
		Service System Development	IP
		Service Transition	IP
		Insident & request management	IP
	Support	Problem Management	IP

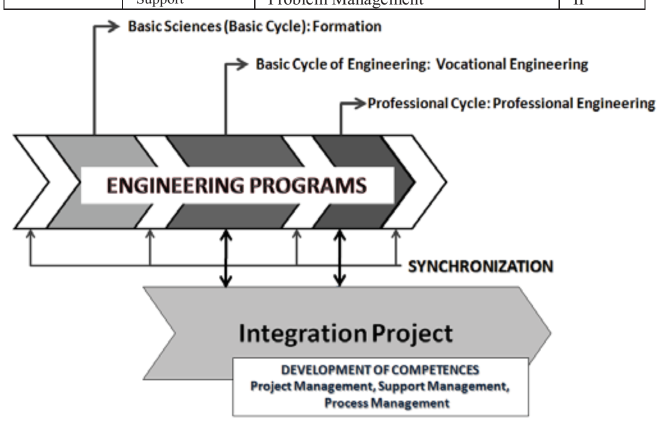


Figure 10. MPECS Project

[1] Relationships between CMMI process areas and MPECS.

The Work in the project covers 5 universities in all regions of the country's strategic and the National Apprenticeship Service (SENA). The roles covered in the project include administrative, faculty and students. Each role is associated with some areas of the CMMI process adapted by the competences-based model for educational sector as shown in fig. 11, establishing the relationships between the curricula development guides for educational programs of the SENA, the Competency Lifecycle Framework (CLF)[2] [10] and the CMMI model as described in Tables V and VI.

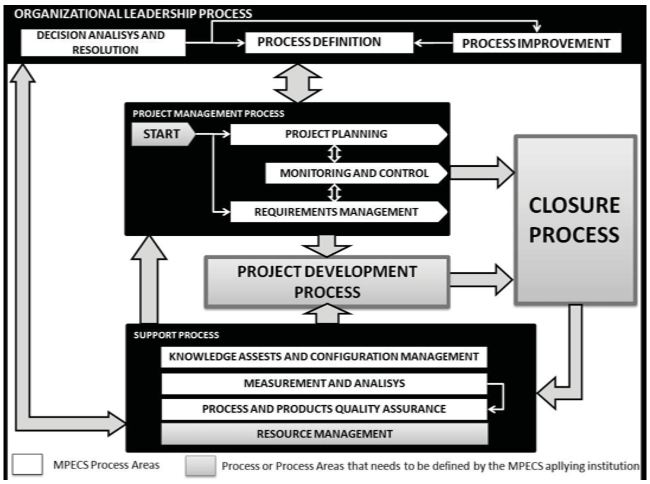


Figure 11. MPECS Prototype Model [8]

Each institution is using MPECS, adapting it to the regional and institutional needs according to MPCES Meeting[3] Strategies [20] shown in Figure No. 12. The Methodology of Meetings covering the project life cycle MPECS: Initiating, Planning, Implementation, Monitoring, Control and Closing. MPCES prototyping has been used for process improvement in Management of business practices, research project management, and degree project management, among others.

The MPCES program roles have been established are: asset managers (learning objects managers), tutors, instructors and assistants. Students play roles of project leader, planners, knowledge managers, coordinators of development and developers.

Upon completion of the prototype implementation MPECS hope to have completed:

1. The benchmarking of the participating entities with respect to the process management, project management and support and their process areas.
2. Proof of certification of competence for all roles we have defined.
3. The benchmarking of the roles, not people, which will allow us to define levels of maturity of such roles.
4. Have established improvements for the problems referred to in paragraph II.E.

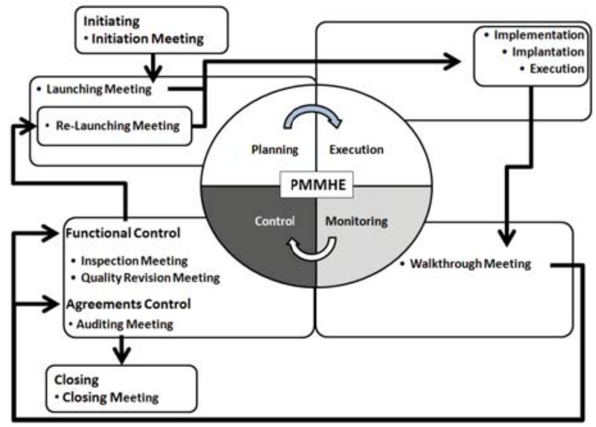


Figure 12. Strategy for development of MPECS prototypes

TABLE V. PROCESSES AND ROLES IN MPECS

Process	Roles
Project Management	Team Leader Planning Manager Leader Manager
Product Development	Design Manager Test Manager Team Member Inspector Manager
Process Management	Process Manager Quality Manager
Support	Support Manager

TABLE VI. RELATIONSHIP BETWEEN MPECS COMPETENCES MODEL AND CMMI MODEL

MPECS Competences Model		CMMI Model
Unit of Competence		Process Area
Competency Cluster [10]	Element of Competence	Practices
	Perfomance Criteria	Sub-Practices
	Evidence required	Work Product
	Essential Knowledges	-
	Other Applications	Amplifications

V. FUTURE TRENDS

With the work we are expected to proceed with completing the following perspectives:

1. Create a benchmarking model for programs of higher education in order to establish objective improvement processes [15].
2. Create a benchmarking model for graduated students.

[2] The CLF is a matrix that identifies the specific competencies required for a particular CMMI-based professional role in the lifecycle phases for each unit of competences. The competency clusters for MPECS are: Achieving and managing agreements; Decision making and problem solving; Project planning and managing; Interpersonal communications and facilitation; Integration, articulation and expression of information; Understanding and adapting to organizational contexts; Model interpretation of the unit of competence; Product or service tailoring, adaptation and application; and, Professionalism.

[3] A meeting is any activity as assemblies, meetings, conferences, inspections or other gatherings that requires careful planning and detailed to achieve the results on each of the processes to develop in each institution to ensure the success of prototype curricular improvement MPCES.

3. Create benchmarking model for assessments leaders, teachers, attendees and educative managers at educational institutions.
4. Develop a software system for integral managing of academic programs based on competencies considering the management, authoring and instruction processes.
5. Adapt and integrate the competency model to be compatible with frameworks of human capital management [19]

VI. Conclusions and Acknowledgments

We have presented in this paper work related to the improvement process in engineering education processes of the institutions of higher education. The paper has shown the ongoing work that has evolved from the research to the implementation of educational quality assurance systems. The document shows how a project from emerging in the software production sector, impacts academic programs, to consider opportunities for improving performance of the graduates as they develop their professional activities. The study discusses the process of learning - formal learning as a competences certification model that impacts all administrators, educators, students and alumni of the educational institutions relationship with engineering.

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