GILABVIR: Virtual Laboratories and Remote Laboratories in Engineering.

A Teaching Innovation Group of Interest.

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Abstract— **GILABVIR (Grup d'Interès en Laboratoris Virtuals I Remots) is a recently created Virtual and Remote Laboratory Group of Interest at the UPC (Universitat Politècnica de Catalunya) and it is integrated in a more general teaching innovation project: RIMA [1], [2]. RIMA has been developed to promote research on the use of innovative learning methodologies applied to engineering education and it was specially created to assess in the new European higher education adaptation process.**

Keywords- Generic skill, digital campus, software platform, laboratory experiment.

I. INTRODUCTION

The GILABVIR Group is formed by high education faculty members who are involved within different laboratory courses, all of them characterized by the use of real and simulated experiments accessed through the moodle based UPC digital campus platform (ATENEA). The experiments in the different laboratory courses usually follow the next three steps sequence: 1.- The student designs the experiment and configures the parameters on-line, either at distance or in the computer classroom. 2.- The experiment is executed. 3.- The different results (numerical, graphical, images, etc.) are displayed and optionally recorded at the student computer and are also optionally recorded at the ATENEA server.

Up the date, there are nine laboratories integrated in GILABVIR and they are used in courses corresponding to curricula of: Electrical Engineering, Telecommunications Engineering, Computing Engineering, Industrial Engineering and Civil Engineering. Technical and didactic aspects of them have been collected and classified. The two main goals of this group are to detect common needs of the technical solutions of the different laboratories and design new educational methodologies that use virtual and remote laboratory based teaching activities.

The first goal is related to the implementation of a software application to join all the virtual and remote laboratories the UPC digital campus (moodle platform) and allow students execute experiments and teachers propose monitor and evaluate these experiments, instead of spending a lot of time developing access and activity management applications. A dedicated software tool (Moodle_LAB) is being programmed in order to control and monitor the access and execution of an experiment. With this option, professors can enable or disable the access to each experiment offered in each course and can also obtain information, individually for each student, about the timing, the configuration parameters or the obtained results. These data are used to evaluate the students. For most of the virtual and remote laboratory based learning activities, professors can obtain automatically a list of numerical results and records.

The second goal aims to improve the students learning outcomes, taking into account the design of the learning activities in the context of the European Higher Education Area, EHEA, both in specific knowledge and especially in generic skills.

Paper Outline—The rest of the paper, is organized in five sections. After an introductory section I, section II is dedicated to define virtual laboratories and remote laboratories, emphasizing the differences and comparative features between them when they are used for learning activities. The virtual and remote GILABVIR laboratories are described. The design and functionalities of the monitoring tool: Moodle_LAB are described in section III. In section IV innovative teaching methodologies based on these laboratories are presented and related to a generic skill list. Finally, the conclusions are described in section V.

II. VIRTUAL AND REMOTE LABORATORIES

The university education environment is becoming more diversified and interdisciplinary in the type of activities offered to students. Virtual and remote laboratories have been developed by combining experimentation, homework and use of information and communication technologies. In this context, when a student executes an experiment at distance, two different modalities must be distinguished: Virtual Laboratories and Remote Laboratories.

A Virtual Laboratory is defined as an interactive environment for designing and conducting simulated experiments. The experiment execution consists in running a program loaded in a remote server machine. To start this program the user accesses the server through a user interface. A software monitoring platform starts the simulator program. The program models some real experiment behavior, producing output signals, graphs and/or data when a set of input parameters is configured by the user.

A Remote Laboratory is defined as an interactive environment designed to allow users to remotely control real laboratories. A monitoring platform is installed in a remote server machine. To start the experiment the user accesses the monitoring application through a user interface and configures an input parameter set. After the experiment, measured data or

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signals are obtained and returned to the user through the monitoring application.

As it can be deduced from previous definitions, virtual laboratories and remote laboratories are extremely similar in the sequence of steps to follow when a practice is executed. Teaching methodologies based on these two kinds of laboratories are also very similar.

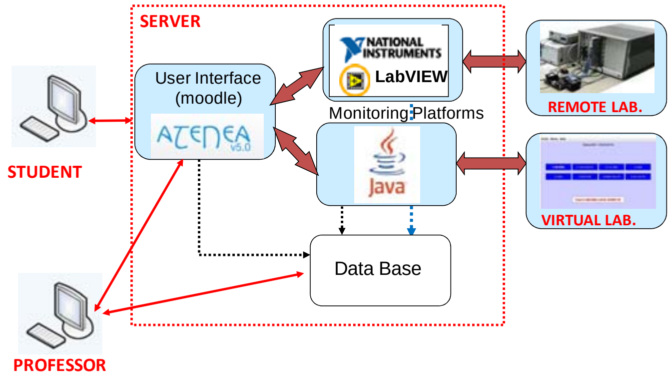

Figure 1. Remote laboratories and Virtual Laboratories are connected to the server through a software platform: Java or Labwiew. Atenea is the user interface (UPC Digital Campus).

Figure 1. shows a functional diagram including the elements that have a main role in this environment. Some advantages and disadvantages when comparing virtual and remote laboratories are displayed on table I.

TABLE I. ADVANTAGES AND DISADVANTAGES

Advantages	**Virtual**	**Remote**
Experimentation with real signals	NO Y	ES
Flexibility and configurability level	High	Medium
System registers user activity	YES	YES
Number of users simultaneously running the experiment.	Unlimited 1	user
Disadvantages	**Virtual**	**Remote**
Workstation booking system is necessary.	NO Y	ES
Software update is eventually necessary	YES YES	
Expensive	NO Y	ES

The GILABVIR group has been formed by faculty members who use virtual or remote laboratories in their teaching courses. Nine different projects directly related to nine different laboratories are currently grouped.

Virtual and remote laboratories that joined the GILABVIR initiative are described in the following list.

A. *Remote and virtual laboratories for mechatronics and enertronics students.*

Different platforms have been designed to allow students to access the m re motely or virtually to complement the local laboratory sessions. The platforms are used in electrical engineering courses related to automation, mechatronics, motor control, renewable energy generation and power systems. Students program and supervise real systems as if they were working with real installations. This is done by using for example standard PLC (Programmable Logic Controller) programming software provided by the PLC manufacturers.

Remote laboratories include: Automation and motor control laboratory [5], Flexible manufacturing cell [6]. Power Quality laboratory, measurements of harmonics for different loads, power system laboratory, protection, fault detection and restoration of electrical power systems.

Virtual laboratories include: DC motor control laboratory, Hotel automation laboratory, Chemical process automation [7].

B. *LAVICAD*

The virtual laboratory of analog and digital communication systems is a useful tool to verify the performance of different communication systems and signal processing techniques, topics typically integrated in undergraduated courses of the curriculum of telecommunications engineering. The communication systems have been implemented and designed as Java applets and are free available. They can be run at the e-learning platform: comweb.upc.edu. The different communication systems present different levels of user interactivity and when students execute a system integrated in a comweb course, the obtained results can be supervised by the professor as an evaluation and assessment tool. From a pedagogical point of view, this laboratory has been created to facilitate the learning of certain matters, acting as a connection between the model of knowledge based on concepts and theories, and their practical understanding and experimentation.

C. *Project: 62, an interactive tool to study discrete time signals and systems.*

62 is an interactive tool written in JAVA that allows, first, to define discrete time signals and systems, and then to work with them. Signals, systems and operations are specified by means of menus or dialog windows without the need of knowledge of any programming language. One of these menus is devoted to specifying digital filters (FIR and IIR) both in the frequency and in time domains. The tool includes a graphic interface to show the sequences, their Fourier transform and the characterization of lineal invariant systems (frequency response, impulse response). The tool uses the A/D and D/A converters of the PC sound card. Thereby, the tool can generate and filter analogue signals in real time. 62 is part of the experimental framework designed for the students of discrete time signals and systems to carry out their practical training. This tool is freely available in [4].

D. *iLabRS: Remote laboratory for Secondary Education.*

iLabRS is built over a Modular platform to perform remote experiments in sensors and signal conditioning. It uses two experiment boards, which together with 3 additional boards

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allow doing currently 13 different practices. This remote Laboratory is aimed for Secondary Education students, to allow them to perform online real experiments, with remote access through Internet. The aim is triple: giving a tool to increase the experimentality in scientific and technological subjects, demonstrating the potential of the ICT's use and establishing a bridge between the secondary school and the university.

E. LEARN-SQL

LEARN-SQL is a system conforming to the IMS QTI specification that allows on-line learning and assessment of students on SQL and other database skills in an automatic, interactive, informative, scalable and extensible manner.

This tool facilitates the definition of virtual laboratories or remote questionnaires that are used by students of subjects to learn design and use of relational databases in the UPC.

LEARN-SQL is a tool whose main goal is helping in learning the use and design of relational databases in different subjects of schools of the UPC. More, specific goals are to:

- Provide the possibility to define virtual laboratories or remote questionnaires to be solved by the students at class or at home.
- Facilitate the participation of the students in its self-learning of database subjects.
- Provide students with valuable feedback, so that they can learn from their mistakes.
- Automatically evaluate the correctness of any SQL statement (queries, updates, stored procedures, triggers etc.) and other relational databases related exercises (Relational Algebra) with independence of the student solution.
- Help teachers define the questions or items in the remote questionnaires as well as allow them to review the solutions provided by the students.
- Adapt the subjects where it is used to the European Higher Education Area (EHEA) and to innovative education methodologies.

F. Circuit and Communications Systems Simulators

This virtual laboratory is still in construction.

The aim is to develop monitoring tools for homework based on running software simulators or remote laboratory experiments. The monitoring tool will automatically send a report to a moodle platform. It will be based in a Python module with functions to write ascii text, formatted text, results tables and figures in the report together with the answer to questions asked to the student.

This project is to be implemented in the following activities of the UPC "European Master of Research on Information and Communication Technologies":

Course: "Antennas for Communications" and "Waves and Systems". Activity: Modeling a WiFi system with intermediate repeater, including modulations and RF.

Course: "Electromagnetics Engineering". Activity: Analysis if a transmission line with impedance discontinuities using many different numerical methods in frequency or time domains. The results of different methods are compared in terms of accuracy and computational efficiency.

Course: "Design and Analysis of RF and Microwave Systems for Communication". Activity: Remote control of a network analyzer using the high-frequency circuit simulator ADS.

G. Modular platform to perform remote experiments in sensors and signal conditioning [8].

It is based on a custom acquisition board which includes a Ethernet capable microprocessor, so that every board has its own IP address. The connection of multiple boards to a switch allows the access to multiple experiments and/or to multiple replica of an experiment. Every board gives power supply and control signals to specific experiment boards that are connected to the control board in a sandwich structure. The signals are 4 A/D channels (16 bits), 2 D/A channels (14 bits), 8 control bits and a SPI bus. The experiment server runs specific applications made in LabView that control the experiments. Every application generates a remote panel that allows its use with a web browser. The link with the remote panel URL is placed among the course materials in the digital campus Atenea. This platform gives a certain degree of security, the user authentication and a basic record of the user activity. Four different experiment boards have been developed up to now, which allow performing 6 different laboratory activities around the sensor characterization and the set-up of conditioning and acquisition circuits. The use of the remote laboratory is focused as a complementary tool to add flexibility to the laboratory courses, mainly with the semi-distance students

H. VirtuaLab: remote workbench for instrumentation and sensors [9].

Remote laboratory based on a web server and a VXI modular instrumentation system connected to a circuit board with experiments and to a weather station. The access is made through a website (virtualab.upc.es) using a password. It only admits a single simultaneous user, who can use the resource during 20 minutes. Seven different laboratory activities can be carried out, from system identification and control, sensor calibration and remote control of instrumentation. In operation from 2003, the user interface was designed with the criterion of minimizing the data exchange and ensuring the system robustness. Because of this, the control applications in LabView that control the experiments are running in the server and they just exchange parameters and results with the user dialogues in the web pages.

I. rWLaB-Remote WaveLab

The goal of this laboratory is to convert an experimental setup (wave channel) into a platform for teaching, research and dissemination of knowledge using all the advantages offered by today's information technologies. Thus, we propose the creation of a knowledge portal based on experimentation with small-scale physical models with in the field of Maritime Engineering. The purpose of this portal will serve as the container of those remote and virtual laboratories that can be developed from this initiative. It is envisaged to provide the necessary content to the portal in order to, either through simulation, experimentation or study, achieve varying knowledge levels of methods and technologies employed in the experimental scale.

III. CONNECTING GILABVIR PROJECTS TO MOODLE.

One of the main technical aims of the GILABVIR group is the connection of all the projects to the UPC digital campus. The UPC digital campus is a based moodle platform and it is called Atenea. In [3] some guidelines are proposed in order to connect virtual and remote laboratories to an educational platform.

Moodle_LAB is the application designed to connect all the at distance laboratories to the UPC digital campus. It is integrated by the connection module JLab and by the booking module.

A. Moodle Connection Module

The connection functionality allows the different at distance offered experiments can be run from a Moodle site. When an on-line experiment is invoked through the moodle platform there are some tasks that are identified to be performed in order to communicate the virtual and remote laboratories with the Moodle database to store practice results and then allow teachers view them.

The application that has been implemented is a new module for Moodle called JLab. JLab :

1. Centralize the management of the simulators that can be used in practices.

2. Allow laboratories to send the results to the server in order to be stored in the Moodle database.

3. Enable teachers to see the results of the practices from the portal and download them in Excel format.

The user enters in to the main portal using any browser. Then the user enters in a JLab practice of any of his courses.

On last page of this paper figure 3 shows the module operation process from the applet request to the results display. This is a communication protocol for a virtual java based laboratory, but the strategy is duplicated for any virtual or remote lab, using Java or Labview as software monitoring platforms.

1. The user enters in the main portal using any browser. Then the user enters in a JLab practice of any of his courses.
2. It shows the simulator applet using javascript embedded in view.php.
3. View.php obtains the id of the user connected, the id of the practice selected and a parameter that indicates if it is necessary to send the results to the server.
4. Applet is loaded.
5. Each stage of the applet, upon completion, generates an xml with the results.
6. This XML is sent to the server, the combeans.php file parses data and inserts them in the table mdl_jlab_results.
7. JLab also implements the report.php file which will show all users results of each practice.

Figure 2. shows the system architecture for at distance laboratories.

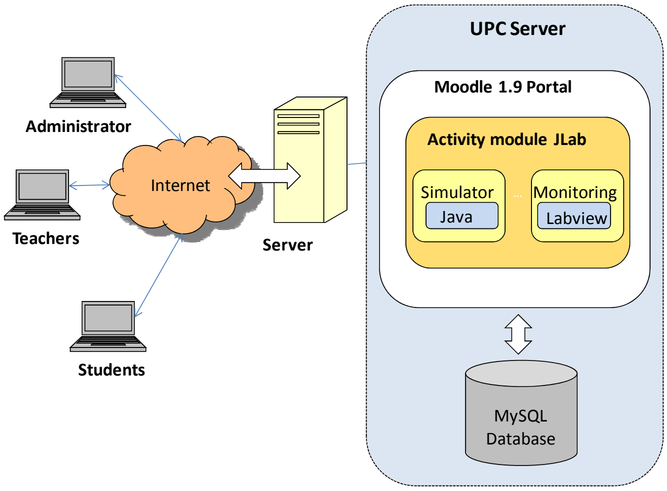

Figure 2. JLab – System Arquitecture.

Jlab module has been currently finished and it is being tested with a virtual laboratory (II.B) and with a remote laboratory (II.D). It is expected to connect all GILABVIR laboratories to Atenea campus on June 2010.

B. Moodle Booking Module

If the experiment is performed in a remote laboratory and the number of local workplaces is limited, a booking planning strategy becomes necessary. A dedicated moodle module is being designed to allow booking functionality and Jlab module coordinately work. The booking strategy defined for ours laboratories integrate:

- Students and teachers can book a workplace session some days in advance.
- A booked session can be modified or canceled
- The occupation time per session is configured by a laboratory administrator
- The dedicated moodle application assigns the workplaces to the booked sessions.
- A workplace inactivity detector releases the inactive workplaces and these are automatically available for other booked sessions.
- Teachers can supervise if a booked session is occupied by its owner.
- Laboratory responsible and teachers can periodically check the statistical books and the statistical use of the workplaces in the laboratory.

The Moodle booking module is currently being tested with a remote laboratory (II.D).

IV. ACADEMIC USE OF VIRTUAL AND REMOTE LABORATORIES

One of the main goals of the interest group is to share and improve the academic activities related with the use of virtual and remote laboratories. Two different aspects have been identified: the insertion strategies (how to use the virtual and remote labs within our subjects) and the learning methodology (what to do, evaluation, incidence in specific and generic skills, …).

After a survey within the group members, we can conclude that the virtual and remote labs are used both in classroom and remote activities. In addition to its remote use by the students, almost all labs are also used as demonstrators in classroom to support the teacher explanation and a half of them in laboratory sessions to enhance the in-situ activities. While one of the laboratories is used as an additional and independent activity and another as a substitutive of current laboratory activities, all others are used as complementary activities. Concerning the assessment, one half of the subjects including virtual or remote laboratories use them as voluntary issues while the other half specifies a given percentage of the mark. To perform the assessment, two of the involved subjects performed an automatic harvesting of results, a third one performed an automatic evaluation of the work and the remaining five performed a classical off-line gathering of reports.

Concerning the learning outcomes, the virtual and remote laboratories should contribute to improve the specific knowledge of the topics included in the respective subjects, but also to boost several generic skills. Among the mandatory skills defined by our University, the survey has shown that the use of virtual and remote laboratories can contribute to acquire the following skills: self-learning (8), effective use of learning resources (4), team work (3), innovation and entrepreneurship (1) and use of a foreign language (1). Additionally, the different schools can define other generic skills like "experimental behavior and instrumentation knowledge" or "engineering problems identification, modeling, formulation and solving". Most of them are also identified as targets of virtual and remote labs.

Several virtual and remote laboratories have born with a higher stress in their technical aspects than in their didactical aspects. An outcome of the Interest Group activity has been the recommendation of planning the virtual and remote laboratories as standard academic activities . That is, with a lifecycle that starts at the subject goals, defines a given learning activity, includes a deliverable that can be assessed and closes the cycle with an evaluation of the laboratory performance based on indicators. The learning activity should incorporate a form which, in addition to the technical content of the activity, gives information of all that aspects to the students. This includes the objectives and assessment criteria of the generic skills to be handled. As an example, table II describes the goals at three depth levels of the generic skill "engineering problems identification, modeling, formulation and solving". Each row in the table represents a different virtual or remote laboratory based activity that can be proposed to acquire the skill. Levels 1 and 2 are suitable for first and second years of an engineering degree and level 3 is proposed for third and fourth years. Goals at level 3 usually also serve to acquire more generic skills, as for instance "Cooperative Learning" and "Autonomous Learning".

V. CONCLUSIONS

The main aims of the GILABVIR group can be divided in two lines. As a result of detecting common needs of the technical solutions of the different laboratories, first line is related to the implementation of a software application to join all the virtual and remote laboratories the UPC digital campus Atenea moodle platform) and allow students execute experiments and teachers propose monitor and evaluate these experiments. The second main line is related to the design of new educational methodologies that use virtual and remote laboratory based teaching activities to improve the students learning outcomes both in specific knowledge and generic skills.

Concerning the learning effectiveness of web based experiments, in [10] a study is presented where their authors conclude that learning performance using dynamic media is significantly higher than those of the static textbook lesson, especially if the dynamic media can support learning when cognitive load and learners' mental representations. Furthermore, based on our experience, we can assure the learning effectiveness of dynamic resources doesn't depends on if they are offered by internet or in a laboratory classroom, but it is highly correlated with the teacher ability to choose the appropriate experiments to be made to work each subject or sequence of subjects in the program.

ACKNOWLEDGMENT

The authors wish to acknowledge all GILABVIR members for their aid and support provided throughout each activity and meeting, the enrolled students who have implemented most of platforms and applications and the RIMA management team for their institutional support.

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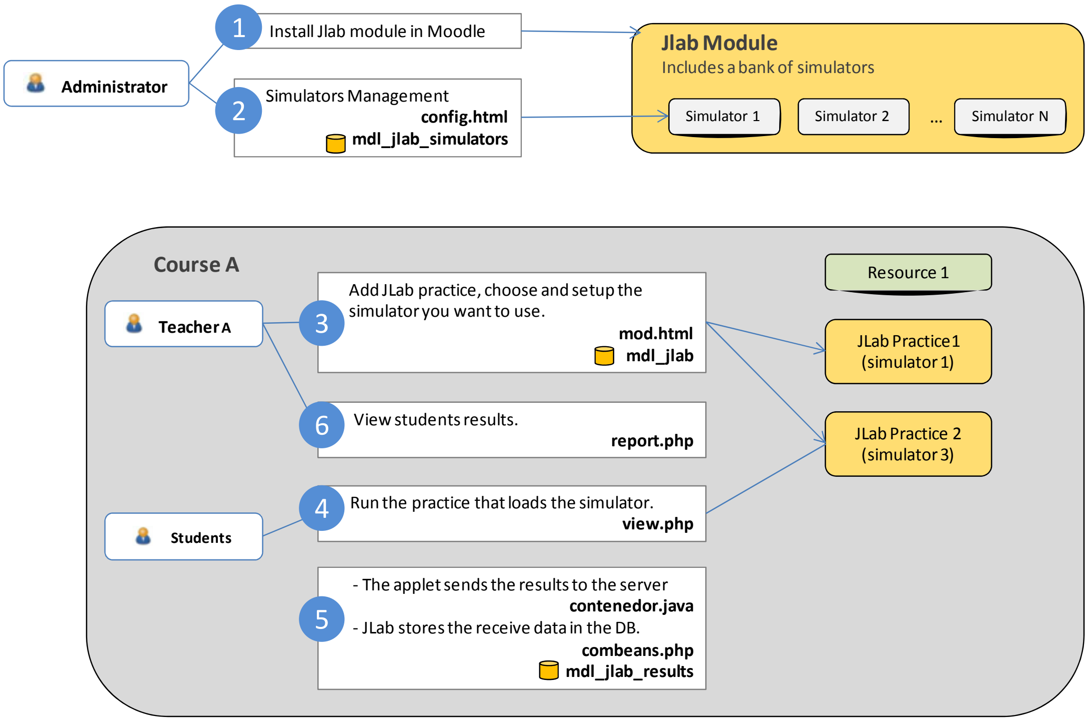

Figure 3. JLab – Module to communicate Moodle with simulators: Functional Diagram.

Table II: goals of the activities that should develop the generic skill "engineering problems identification, modeling, formulation and solving"

	Goals		
Virtual and remote laboratory uses	**Level 1** To perform a guided activity	**Level 2** To perform an open solution activity which includes a partial system or sub-system design	**Level 3** Design and assessment of a complex system
As a complementary activity of a theoretical exercise	To solve a guided theoretical exercise with the aid of a virtual or remote lab as a verification tool. Their configuration parameters are given by the exercise statement	To solve a non-guided theoretical exercise and to verify it with the aid of the lab. The lab configuration parameters are given by the exercise solution	Design of a new subsystem that becomes necessary to solve a given, complex problem
As a complementary activity of a laboratory practice	Use of the virtual or remote lab to help knowing the instrumentation, preparing a given in-situ practice or confirming their results	Use of the virtual or remote lab to perform non-guided activities that reinforce the in-situ lab activities and help analyzing their results	Design of a system or sub-system with the help of a virtual or remote laboratory. Validation in the in-situ lab.
As an independent, remote activity (e.g. remote access to a singular resource)	To perform a guided activity using a virtual or remote laboratory as a demonstrator	To interacting with a virtual or remote laboratory with modification of parameters	Design of a new building block for a virtual or remote laboratory