Experiences in using a MUVE for enhancing motivation in engineering education

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Abstract— **NUCLEO is an ongoing research project that aims at developing a MUVE (Multi-User Virtual Environment) platform for collaborative learning, which uses a role game and a virtual fantasy world to stage a problem-based collaborative learning strategy. The project has four main objectives: (1) to stimulate a change of attitude among students towards studying, forcing them to change their passive listener role to a more active role; (2) to increase students' motivation by adjusting the visual features and the interface of the environment to the peculiarities in the way members of the net generation interact with contents and process them; (3) to help to develop communication skills, teamwork abilities and soft skills in our students, while at the same time they acquire the knowledge and technical abilities included in the subject curriculum; (4) to integrate the platform into an e-learning management system application as a way of centralizing the data management, while at the same time offering the chance to combine it with the use of other instructional strategies that can be applied to wider contexts. This paper introduces the reference framework under which the NUCLEO system has been developed, along with the specific model designed to fulfil the objectives mentioned above.**

Keywords-Computer supportted collaborative learning, Virtual Larning environments, Problem Based Learning.

I. INTRODUCTION

Traditional learning strategies are generally based on the revision of contents carefully structured by the teacher and on solving series of exercises organized by themes following an increasing level of difficulty. Also, they usually rely heavily on textual static content with few interactive features. Several analysts [5],[11] sustain the hypothesis that young people today are reluctant to focus their attention on this sort of content format, because of the way the process and interaction with contents has been deeply affected by their everyday exposure to multimedia and ICT devices.

These factors, along with several other related problems, such as, for instance, increasing dropout rates at all education levels, have led the educational community to try new ways of learning, particularly those that seem closer to the aesthetics and the high level of interactivity the net generation seems to prefer, such as educational videogames.

However, this kind of approach doesn't seem to fully satisfy any of the stakeholders in the educational process so far. On the teacher's side, learning with games drags on, is often centred on wrong motivations (i.e. winning instead of acquiring knowledge), and achieving specific learning objectives becomes a difficult task. On the students' side it is generally believed that educational content diminishes the pleasure of playing to a considerable extent.

Moreover, other than a few exceptions [8], most of the game based learning approaches have been developed with no regard to the tools for managing the whole educational process that presently have the highest level of acceptance among educational institutions: Learning Management Systems (LMS). We consider this a big mistake. Not only because it would be recommendable to pay off the huge investments made until now, or to take advantage of the advancements concerning the standardization process of many of LMS features (contents, run time environments, sequencing, learning strategy design, profile management, exams), but also because LMS are wide scope applications that comprehensively manage the whole learning process (in many aspects unreachable by necessarily more limited applications such as videogames). The fact that their interfaces and interaction mechanisms not longer seem to be fully attractive to the net generation does not invalidate their functionality. From our point of view, the goal is rather to complement their functionality with richer modes of interaction, while taking advantage of the developments and the advances already achieved.

The NUCLEO e-learning project has been under development and testing during the last three years in actual academic learning courses in the Electrical Engineering Faculty at the University Complutense of Madrid. It contributes to the research of new ways of learning in the following aspects:

- It seeks to promote a change of attitude among young learners in such a way that they have to abandon the passive role they play throughout their training.
- We look for an effective learning process targeted to achieving specific curricular objectives, and designed to be attractive to the current generation, as well as

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increasing motivation by applying the formats and interaction modes the "digital natives"' prefer, and reaching a compromise between learning and amusement which reasonably satisfies both parts implied (teachers and students).

- It promotes the development of team work, leadership abilities, and communication skills in the students. Traditional learning strategies are mainly focused on developing students' technical abilities and knowledge acquisition, while today's job market demands a wider range of personal abilities, among which those related with handling work coordination within a team are specially valuable.
- It achieves integration into an LMS, on the idea that the tools developed under the proposed reference framework can be complementarily used with other learning strategies, designed and managed through an LMS. Therefore we obtain a twofold benefit: we increase cost effectiveness, on one side, and we increase the pedagogical range and the target audience of the application on the other side.

The rest of the paper is structured as follows. In Section 2 we introduce the reference framework in which the NUCLEO system was developed. This reference framework is conceived as the baseline model for developing e-learning teaching approaches targeted to complying with the learning needs of a particular population context in a particular situation, and for integrating such approaches in an LMS. In Section 3 we introduce the specific framework developed for the NUCLEO e-learning system, which was benchmarked at the experimental level with extraordinarily promising results relating to the first three objectives mentioned above. Finally in Section 4 the experimental results obtained so far are briefly presented together with some conclusions as the outline for our future work.

II. A REFERENCE FRAMEWORK

The reference framework we propose in this section identifies the main components and interfaces for the development of e-learning solutions targeted to a specific situation, while allowing its integration with an LMS. We depart from the hypothesis that there are no absolute models for teaching and learning, but instead one application will work better or worse at reaching certain learning objectives depending on the targeted audience (social context). Therefore we consider it important to hew closely to a comprehensive system that allows for managing different strategies and solutions, and provides a centralized database in order to maintain continuous learning processes.

At its highest level of abstraction, the framework is organized into five components (see Figure 1):

- *Underlying pedagogical stream*. Its choice will condition the remaining layers, since it is related to the concept itself or the nature of learning, which is to say:

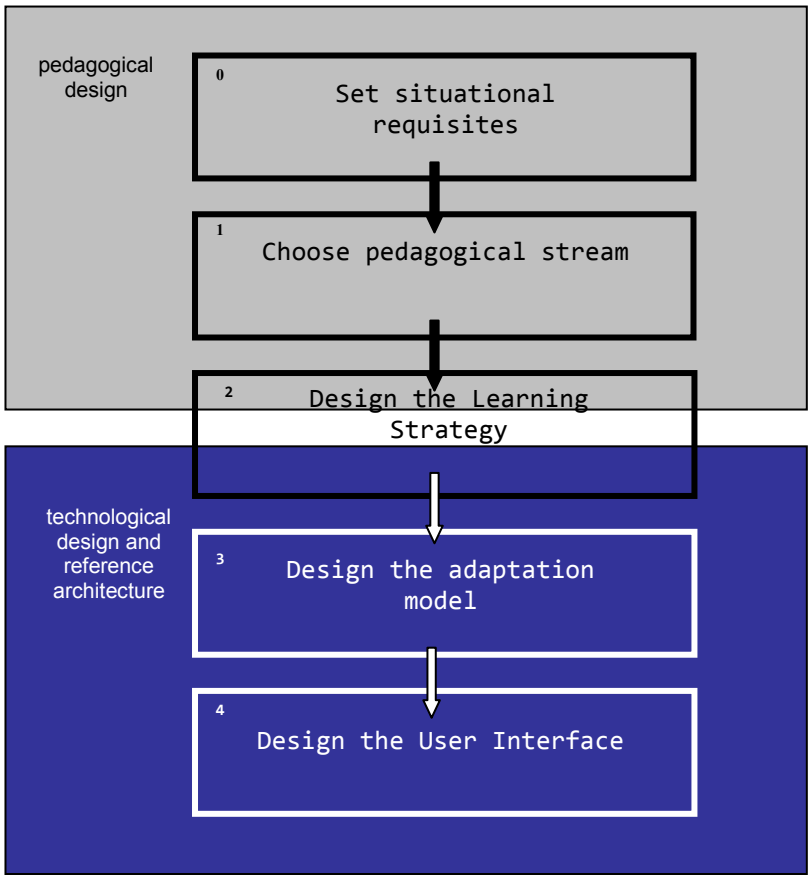

Figure 1. Reference framework used for designing NUCLEO system

what the meaning of learning is and how to achieve it according to a series of generic principles.

- *Learning strategy*. A learning strategy is a particular specification about how to undertake a learning process. It is in the strategy where all the elements in the learning process are defined as well as the way in which they are executed. The definition of a strategy is conditioned by the underlying teaching approach as well as by the definition of the adaptation processes (which in some cases affects all or a part of the elements in the strategy).
- *Adaptation*. Adaptation is the learning system ability to customize certain aspects of the learning process in terms of certain student characteristics (including previous knowledge, preferences, limitations, personality, learning styles…), founded on a series of predetermined rules. The pedagogical stream has influence over the adaptation layer's existence (since from cognitivism onwards all streams consider that each individual reacts in a different way when he/she is placed in a learning context), and the learning strategy determines what, how and the terms of what the adaptation must achieve. In turn, the adaptation process itself also has influence over the strategy, determining which specific aspects must be modified. Therefore these two layers are interrelated.
- *User interface*. The user interface for an e-learning system is the way of communication and interaction between the learning strategy layer and the student. In other words, the interface is the main element for the staging of the learning strategy.
- *Interface with the LMS*. The interface with the learning management system acts as a mechanism for exchanging information between the situational application and the LMS. The situational application is specifically conceived for a particular context. The LMS is in charge of managing all the processes and data implied in a comprehensive context supporting the continuous learning.

III. USING THE REFERENCE FRAMEWORK FOR DESIGNING THE NUCLEO SYSTEM

This section explains the specific model designed for the NUCLEO system, using the reference framework depicted in Section 2, regarding what we have defined as "situational requirements", which are as follows:

- *To whom is the tool targeted*? At a first stage of the project development, the tool is targeted to the current university population, which belongs to the so called "net generation". The students that belong to the current generation are used to accessing information in a discontinuous way, jumping from one subject to another, and they would rather use multimedia digital formats than textual printed ones; they prefer interactive hypermedia contents to static ones; multitask working is easy for them, and they are used to being permanently connected with their peers (e.g., through instant messenger tools). They also feel uncomfortable if they do not obtain quick feedback and immediate responses.
- *What is the application context?* Our tool is mainly targeted to higher education in strongly practical content domains.
- *What are the learning process objectives?* We pursue three main objectives: driving students toward the development of skills for team-work, communication (soft skills), and problem-solving; promoting a change of attitude among students that turns them into active learners; and increasing motivation, while trying to attain learning specific goals included in the subject curriculum.

A. Underlying Pedagogic Rationale

Taking into account our situational requirements (namely, turning students into active actors concerned with their own learning, and promoting the development of skills for real problem solving in complex situations, along with soft skills), we have opted for an approach strongly rooted in the socio-constructivist pedagogic stream [12], [16]. Specifically, we use a problem-based collaborative learning system, or PBL ("Problem Based Learning"), whose original scheme was developed more than thirty years ago by Neufeld and Barrows [9]. This sort of strategy has been often implemented in collaborative e-learning environments or CSCL environments (Computer Supported Collaborative Learning or sometimes Computer Supported Cooperative Learning), even though tools included in CSCL cover a wider set of applications that can be sustained by different pedagogical approaches [13].

While in traditional environments tutors are responsible for providing and organizing the information and providing students with contents in a structured way, in PBL environments the students acquire knowledge during the process of solving complex collaborative problems. Therefore, the tutor role changes from being the sage on the stage to being a guide in the process of finding a solution. He provides hints and encourages the students to seek the information and knowledge sources. In spite of the unquestionable pedagogical values socio-constructivism in general and PBL in particular provides [6], it is not easy to implement PBL, especially in a non face-to-face setting. Three of the main reasons are:

- The tutor must do a comprehensive follow-up of students, leading them and giving them clues and feedback, tasks that considerably increase his/her teaching load, since he/she is forced to conduct and supervise the steps of many small groups.
- The effectiveness of a collaborative learning process is highly related to group dynamics. The success of the educational experience relies deeply on the capacity to handle effective coordination among the members of the work group. In extreme cases, being part of an ineffective team, whose members do not establish suitable collaborative dynamics, can be frustrating and end in withdrawal [1].
- The creation of social bonds among participants seems to be the one of the keys to establishing effective collaborative dynamics. Nevertheless, it is not enough

to form the groups and to provide the students with some support for communication in order to develop the appropriate dynamics [4].

In the NUCLEO system the remaining situational layers (the learning strategy, the adaptation model and the user interface), are designed with the aim of establishing an effective model of collaboration that will lead to a more effective learning process, while at the same time reducing the tutor´s teaching load.

B. Learning Strategy

As already mentioned, the learning strategy used in NUCLEO follows the classical scheme for PBL approaches, according to which students must collaborate in small groups to solve complex, ill-structured, real world problems. The difference is that in NUCLEO the real world is a "fantastic" one. Problems are embedded in a game narrative, and solving them is part of the game. Instead of trying to disguise the educational aspect inside the game, as is most commonly done in some game based learning approaches, we have turned the whole learning setting into a game, on the idea that playing and solving problems share many features [14].

The baseline metaphor leads the students to a fantasy world in which they play the role of warriors trained to face a threat against their civilization. During the training, organized in teams, they will have to confront "assigments" simulating real danger situations, in order to reach the grade of “Paladins” for which they compete individually and in groups, with the aim of obtaining the best score (the idea was inspired by the book "Ender´s Game" by Orson Scott Card). Once this setting is introduced, we proceed to test the students by placing them in an active role, so that they are considered candidate warriors for the Paladins corps, and it is on their shoulders that the survival of the civilization lies.

As in any classical PBL method, groups have to solve a practical case. In NUCLEO assignments represent practical cases in the domain of knowledge that follow the narrative of the baseline metaphor. Hence, they must be solved by a team in which concrete functions and responsibilities are assigned to each individual by means of his/her role (teams as well as roles are determined by the adaptation model).

C. Adaptation

The adaptation model in NUCLEO aims at improving the team’s efficiency, which produces a comprehensive improvement in the learning process and a lesser teaching load for the tutor. With this objective in mind, we are using two combined strategies:

- *Formation of heterogeneous teams*. The aim is to avoid the grouping of the students with the most effective learning strategies together, while leaving the less effective ones on the same team, which would bring about the subsequent impoverishment of the whole learning process [10]. We use the framework proposed by Vermunt to distinguish the students with the most effective learning strategies [16] from the ones with weaker strategies, in order to place at least one strong student in each group, since one of the principles implicitly assumed in collaborative learning is that students learn from each other.
- *Assignment of functional roles*. The roles are assigned to each student by means of his/her profile according to Vermunt's model, which is initialized and maintained through a user-modelling process.

The adaptation cycle follows the same cycle the learning strategy does: in every mission teams are reconfigured, and roles are reassigned. It is performed directly in the Moodle LMS. We have developed an automatic grouping manager tool

Figure 2. Air perspective of Dragon Island.

that it is installed as a plug-in in the LMS.

The group manager takes the result of the Vermunt Inventory of Learning Styles as

D. User Interface

Many studies have shown that the user interface is a key feature to attract the students' attention and interest [7]. An attractive interface may encourage students, while increasing effectiveness of learning. Besides, it may contribute to developing students' ability to perceive, organize, integrate and remember information. On the contrary, an unsuitable poorly designed interface may have an influence in lowering student's interest and even in withdrawal. As mentioned above, the kind of interface chosen for NUCLEO, as well as its design, is oriented to bringing the learning environment closer to the net generation's preferences and peculiarities. But that is not our only objective. We also pursue the student's identification with his/her avatar, the immersion atmosphere and its positive influence in establishing social bonds to improve the collaboration scheme and foster the sense of belonging to a community of practice. And finally, our third objective is to provide the setting and narrative for turning the typical PBL setting into a game, thus contributing to the student's immersion in the story.

NUCLEO also provides 3D settings to stage the two existing levels of social interaction: collaboration among members of the same group occurs inside a ship, while intragroup interaction among all participants in the course takes place in the Dragon Island, a space station with different areas linked to different educational functionalities (see Figure 2).

In addition to this, to foster the sense of competition, student avatars acquire differential features in terms of their intellectual achievements, and individual and team scores are public, as it has been observed that one of the most powerful incentives for the players in MMORPG (Massive Multiplayer Online Role Playing Games) environments is the social recognition by the community of users [2].

E. Interface with LMS: a bridge between MUVES and LMS

The use of digital games and Multi-User Virtual Environments (MUVEs) as educational tools has drawn significant attention [3]. Digital games engage users with challenges that take place inside immersive narratives using realistic artificial scenarios, where students can formulate hypothesis and test them in the virtual world. Hence digital games are an ideal channel to promote relevant educational aspects such as problem-solving skills or analysis and reflection.

Nevertheless, as recent research reveals [15] most of the educational gaming approaches present a lack of balance between educational value and fun, which is the game essence.

Also, the use of digital games and MUVEs has some drawbacks that have not been totally addressed yet. For instance, digital games and MUVEs are rarely fully integrated

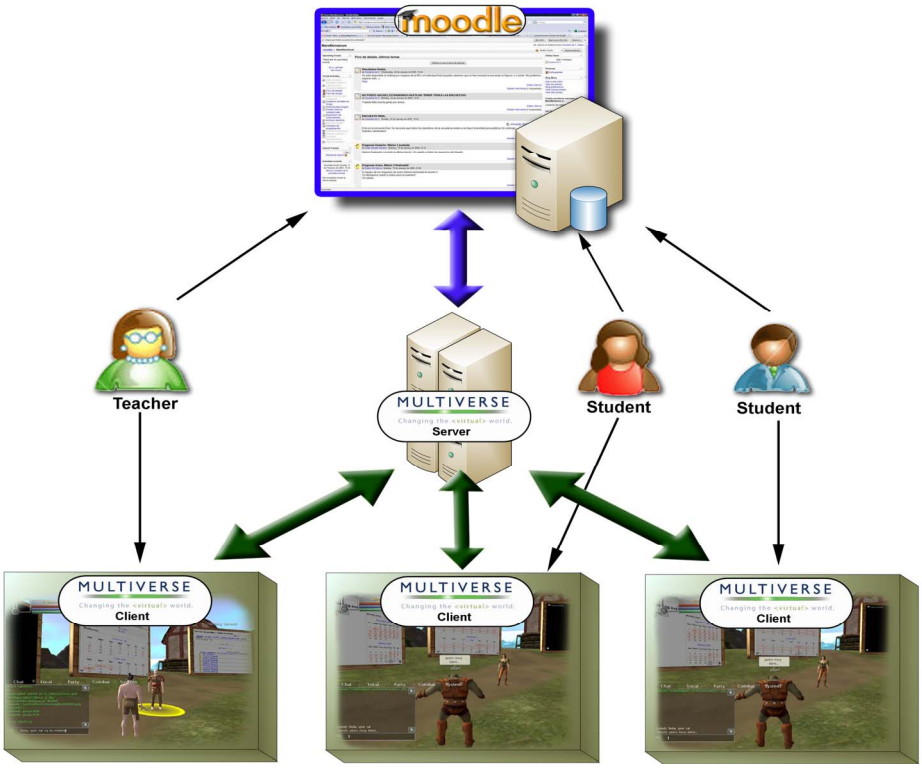

Figure 3. Reference architecture for the NUCLEO framework

in the educational infrastructure and behave as "black boxes". Thus it is impossible to get any instructionally relevant information about the course of the game-based learning experience, such as students' performance for assessment or keep a persistent student historical record.

These issues could be addressed by taking advantage of the already deployed e-learning infrastructure. Many educational organizations are using modern LMS not only for distance learning but also as a complement for traditional lectures (an educational trend usually known as blended learning or b-learning). Those LMS (e.g. Moodle, Blackboard-WebCT, Sakai, etc.) are not only content repositories, but rich web-based systems, that provide instructors with tools to track and evaluate the performance of the students, keep a record of each student or to promote communication and collaboration between students (i.e. collaborative learning). Thus a synergy between educational gaming and e-learning could bring together the benefits of both worlds.

This is precisely one of the key issues where the NUCLEO project aims to contribute. NUCLEO is an instructional framework that integrates a 3D MUVE with an LMS (Figure 3 shows the reference architecture). NUCLEO is conceived to be used as a plug-in application over an LMS, therefore, services, tools and data are managed in a centralized way at the same time that simplifies its integration in the educational infrastructure.

IV. BRIEFING OF EXPERIMENTAL RESULTS AND CONCLUSIONS

The significant hypotheses on which the framework proposed in Sections 3 and 4 is based have been benchmarked at the experimental level during the 2007-2008 and 2008-2009 academic years in three different settings of higher education. So far, we have obtained rather promising results because dropout rates have dramatically lowered compared to the previous years in which a traditional pedagogical strategy has been applied (see Figure 4 and Table 1).

STATISTICAL DATA FOR DROPOUT RATES FOR THE 2005-09 PERIOD.

Academic year	Pedagogical approach	Students enrolled	Students attending the exam	Dropout rate (%)
2005-06	Traditional	115	43	62.61
2006-07	Traditional	110	33	70
2007-08	Traditional	38	13	65.8
	NUCLEO (Mundo Nucleo)	22	20	9.09
2008-09	NUCLEO (Mare Monstrum)	54	45	16

In addition, in 2008-09 students filled a satisfaction questionnaire to collect their opinion over different issues related to the system, including what was the perceived effect of using a virtual world as user interface as a motivating factor. The question was: "In your opinion, has the 3D virtual world GUI affected your motivation?". 51% of the students thought the MUVE was a positive motivating factor, while 41% thought it caused them a delay in their learning duties and was unnecessary. The rest considered the virtual environment as neutral in terms of motivation.

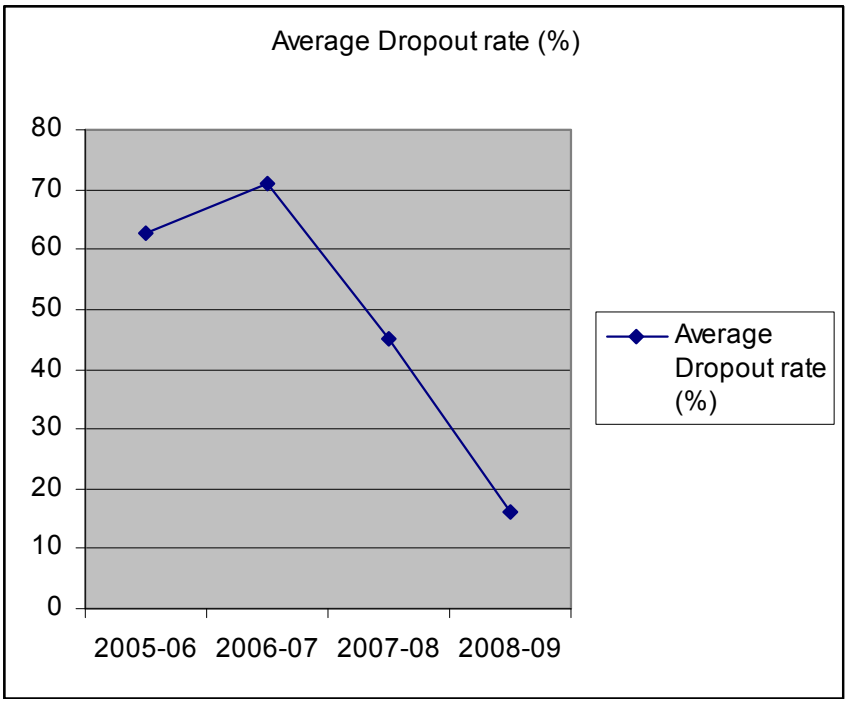

Figure 4. Evolution of the dropout rates through 2005-2009 period.

Even though this evaluation is just a starting point, and more practical research has to be performed in order to establish final conclusions, taking as a base the results obtained in our experiments, we can extract the following conclusion: Fantasy and gaming are powerful motivators, but representing them in immersive 3D multi user interface, with powerful graphics, does not seem to be as important as the gaming or the learning strategies themselves.

During the actual academic year more research is being performed in order to get a more concluding result. Potentially, we consider that this sort of environments would increase its benefifts when teaching less structured subjects, in which it is much more difficult to formalize knowledge and therefore to acquire the skills pursued (e.g. in working-team management and leadership skills). We think it opens a wide field of uses for business training.

Next steps in the project are to obtain a more complete MUVE, easier to install, with improved teacher support and to extend its usability for other knowledge domains different from programming courses.

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